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Marine Research
1961 No. 4

The Oceanic and Bathypelagic Plankton of the North-East Atlantic

and its possible significance to Fisheries

By J. H. FRASER, D.Sc., Ph.D., F.R.S.E.

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Marine Laboratory, Aberdeen — November, 1960

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The Oceanic and Bathypelagic Plankton of the North-East Atlantic and its possible significance to Fisheries

INTRODUCTION

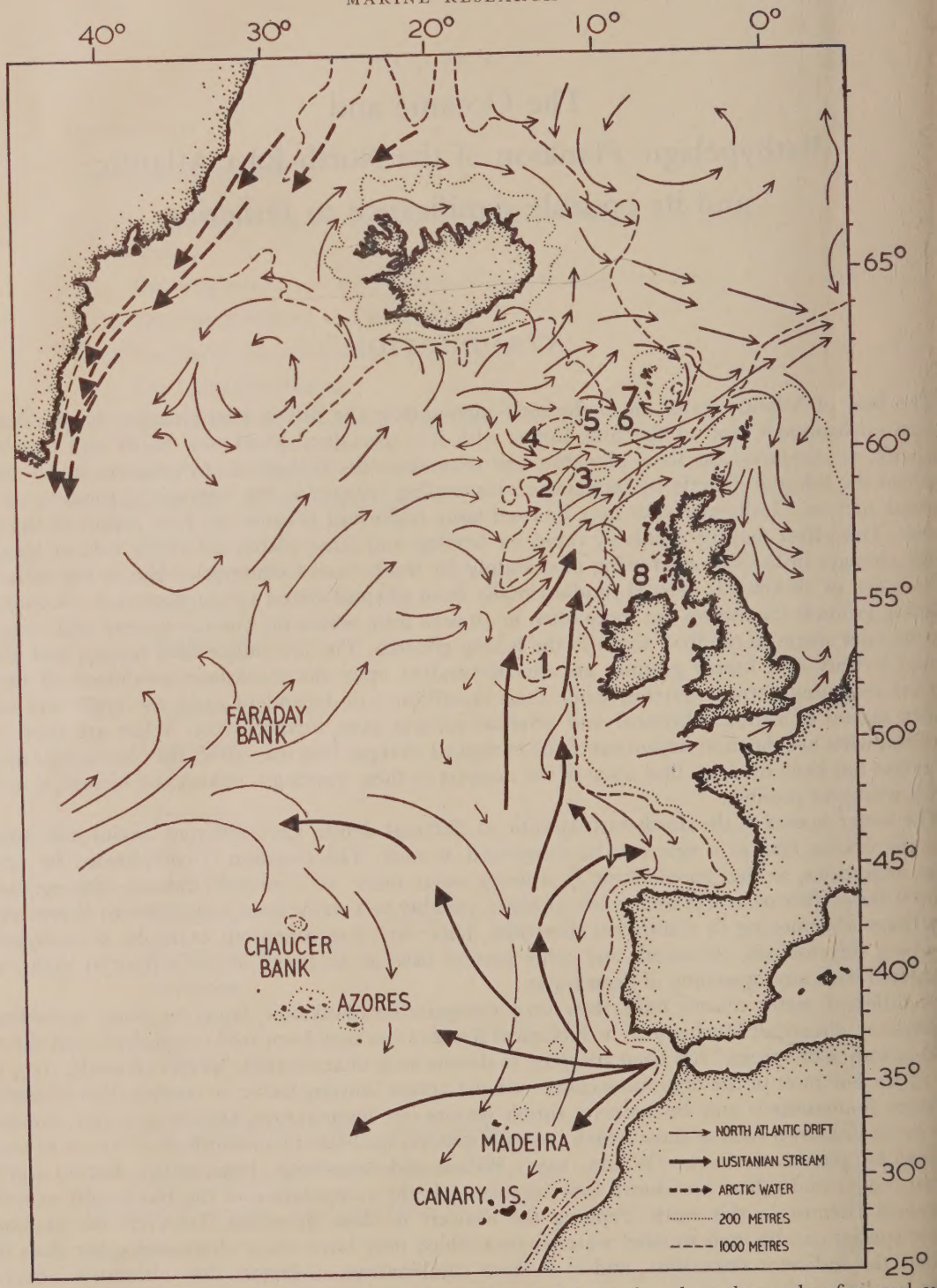

Fig. 1 Chart of the oceanic current systems of the north-east Atlantic based on the works of several au

1 Porcupine Bank, 2 Rockall Bank, 3 Rosemary Knoll, 4 Lousy Bank, 5 Bill Bailey Bank, 6 Faroe 7 Faroe Plateau, 8 Stanton Bank.

The thickness of the arrows is not intended to indicate the strength of the current.

THE CURRENT SYSTEMS

The current systems on the eastern side of the North Atlantic have been fairly well plotted by drographers—e.g. Helland Hansen and Nansen (1909), Jacobsen (1929), Tait (1930-37, 1934 and 57), Vallaux (1936), Hermann and Thomsen (1946), Einarsson and Stefánsson (1953), Tulloch and it (1959) etc. A composite figure, reproduced here as Fig. 1, has been taken from various sources luding some unpublished data from the cruises of the Scottish research vessels. Although it is not posed to attempt to give any authoritative picture of the current system in this essentially biological ber, it may be useful to give a brief summary.

The main inflow of the North Atlantic Drift follows a broad path in the open ocean and towards European shelf it splits into two main sections, one going north-east to the Faroe Channel and the er eastwards along latitude 50°N and again splitting. The main part of the latter goes south between Azores and the continental shelf, and the other and smaller part turns north along the Irish shelf, mately to meet again the northern section which has divided to go on both sides of Rockall. The thern main stream in part continues through the Faroe Channel via the Norwegian Sea to the Barents , giving a branch to the North Sea round the north of Shetland. The remainder of this main northern eam reaches the Icelandic shelf, forming a clockwise eddy round Iceland with an anti-clockwise eddy the Reykjanes Ridge and a clockwise eddy round Faroe; it overflows near the surface at the Faroe-land Ridge. There are also overflows on to the shelf around the British Isles which affect the Celtic Sea he south of Ireland, the west Scottish and Irish areas of the shelf in a southerly trend, and the north ttish shelf, the last tending to continue to the Moray Firth area of the North Sea via the Orkney passages.

The deeper layers have different origins according to whether their greater density is derived from reater salinity or a lower temperature. The chief source of more saline waters in the north-east Atlantic he Mediterranean Sea—the deep outflow from it spreads out through the Straits of Gibraltar—l its process of mixing has its own very real significance in the formation of oceanic water masses in the n ocean (Defant, 1955). Although it is usually very well mixed before any part of it reaches the British s it can at times be recognised beyond Porcupine Bank to Rockall (Neilsen, 1912) and even in the oe-Shetland Channel. Thus Tait (1955) found hydrographic evidence of such water there, for example, May 1948, August 1951 and November 1952, and Fraser (1955) found planktonic evidence of its ct reaching Shetland in the autumn of 1953. This Mediterranean or Lusitanian influence underlies open Atlantic water at some 1000 m off Gibraltar, gradually ascending as it moves northwards, so t in due course it overlies the colder bottom arctic water.

Apart from the East Greenland current the arctic water in the Atlantic to the west of the British s is all deeply situated. The volume transport in the different paths it takes to reach these latitudes till rather doubtful and indeed may be very variable, but the important routes are over the Faroe-land Ridge, and between Greenland and Iceland, in the depths between 300 m and the sill depths about 550 m (Cooper, 1955b; Dietrich, 1956). These cold water masses sink into the depths of the rth Atlantic Basin, probably intermittently as large discrete boluses (Cooper, 1955a); in the North antic Deep the currents may normally reach speeds of 9·2 cm/sec or an occasional maximum of 4 cm/sec—i.e. $4\frac{1}{2}$-$8\frac{3}{4}$ miles per day (Wüst, 1955). The precise movements of this arctic water are, of rse, closely bound up with the bottom topography.

Any deep flow from higher to lower latitudes must be replenished by an opposite flow of warmer face water, and Cooper (1955b) puts forward the hypothesis that extreme low temperature in the tic will result in the cooling and sinking of increased volumes of water, thus giving a greater recruit-nt of deep water in the North Atlantic. This in turn will lead to an upward displacement of nutrient water towards the productive layers in the euphotic zone, especially against continental slopes.

The currents depicted in Fig. 1 can be taken as typical of "average condition" but there are wide iations, both seasonal and annual, which change this pattern. Such variations are due to meteorological ditions, to varying volumes of the different elements comprising the whole and to internal waves at junction of the water masses. These variations can have far-reaching effects on the ultimate dis-ution of the inflow over the continental shelf which, of course, carries the chemical and biochemical ations which are revealed by the plankton indicator species.

Further local variations of the general current pattern are caused by topographical features. S banks rise above the level of the cold bottom water and sufficiently far into the upper layer to affec course. This effect may be a simple splitting of the main flow, leaving a surface oceanic stream to over it, e.g. Lousy Bank (200 m); or the bank may be sufficiently large to cause eddy formation so part of the body of water above the bank stays there in circulation, e.g. Rockall. When this hap the winter conditions are right for the formation of a cascade (Cooper and Vaux, 1949). The sur layers, cooled by the atmosphere, sink and cascade down the slope to a deeper level, to be replace relatively warm surface oceanic water, and so the process is repeated until the atmospheric condi are sufficiently warmed in the spring.

This, then, is briefly the general hydrographic background on which to fit the oceanic plan distribution; it will help in the appreciation of the significance of the plankton distribution on the tinental shelf and its ultimate significance to the fisheries.

THE CHARACTERISTIC SPECIES OF THE VARIOUS WATER MASSES THAT AFFECT THE SCOTTISH AREA

The main masses are:

(1) the indigenous North Sea and other indigenous waters,

(2) the mixed Atlantic and indigenous water that occupies much of the shelf area, including northern North Sea, the shelf west and north of the British Isles, the Faroe Plateau, Icelandic shelf, etc.,

(3) the open Atlantic water—the North Atlantic Drift,

(4) the Lusitanian stream, containing mixed Mediterranean and sub-tropical Atlantic wat

(5) the arctic, sub-arctic and boreal water.

Although an attempt to distinguish five water masses has been made, and at times the bound between them are clear, particularly as strata, they can and do intermix greatly during their pro as moving masses so that sharp boundaries are rare and the edges diffuse. There are also natural varia in tolerance and preferences in the physiology of the plankton organisms as well as seasonal chang distribution and diurnal vertical migration, so that there cannot be any very sharply defined list ap able to one water mass, and that alone. Nor can abundance of a particular indicator species be rel entirely to the volume of inflow of the water to which it belongs (Farran, 1933); it may have particularly abundant, or scarce, in the area of origin, or conditions may have been suited to its re duction en route so that masses of young individuals develop in an area as distinct from the relat few that have themselves been brought into it. Nevertheless, in spite of these well-known complicat it is possible to use certain organisms as indicators with a reasonable degree of reliability, and t groups of indicator species as communities or associations with a much greater reliability.

As Russell (1935a) emphasised, to be of value a plankton indicator species must be a *practical* indic It must be easily identified, preferably by naked eye on board ship, and short lists of easily recogn forms are of more practical value for this particular work than long lists of possibilities. These wi dealt with in the next section.

Work of this kind has now been done by many workers in different parts of the world, such to mention but a selected few—Gran (1902), Ostenfeld (1908), Damas (1909), Russell (1935 a, b, 1939, 1952), Fraser (1937, 1939, 1949, 1952, 1955), Bigelow (1938), Parker (1939), Allen (1940), Rec and Beale (1940), Thompson (1942), Clarke, Pierce and Bumpus (1943), Moore (1949), Kändler (1 Dunbar (1951), Williamson (1952, 1956 a, b), Hela, Moore and Ower (1953), Pierce (1953), Ber (1955a), Blackburn (1955), Bumpus and Pierce (1955), Wiborg (1955), Abramova (1956) and Hida (1

The use of the planktonic larvae of littoral benthos as indicators of the intermixing of coastal v in offshore waters also has its value (Gran, 1902; Russell, 1935a; Rees, 1952, 1954a, b; Kitou, 1

Not only are indicators used to define water masses of various marine origins, but also to d

eas affected by land drainage, e.g. Komarovsky (1953) uses the presence of the cladoceran *Podon yphemoides* to indicate the presence of Nile flood water off the Israel coast.

For the North Sea, English Channel, Irish Sea and the main masses of water mixing with these, e best groups of organisms to use as practical indicators are the Chaetognatha (Russell, 1935 a, b, 1936, 39; Pierce and Orton, 1939; Fraser, 1937, 1939, 1952), the Thaliacea (Fraser, 1949) and certain oups of copepods and pteropods (Rae, 1953); indeed these same groups have proved to be the best many other areas with similar characteristics. Out in the open ocean, however, the physical or micro-emical similarities between adjacent water masses are much closer and it is then practicable to use ganisms with much finer tolerance limits, organisms that soon die if transported into slightly changed nditions. Perhaps one of the best groups of indicators in this area is the Siphonophora. Until recently, s group has been regarded as a specialists' group, with much justification, but the work of Totton 54) and the publication of Plankton Sheets 55-62 by the International Council for the Exploration the Sea should help to make them familiar to the non-specialist. Other useful groups are the medusae, ropods, euphausids, Thalicea and pelagic polychaetes, from all of which helpful species can be ected.

The indicator species of the first two main water masses mentioned have already been dealt with ewhere—see, for example, Russell (1935 a, b, 1936, 1939), Fraser (1937, 1939, 1952), Williamson 52, 1956 a, b), Rae and Rees (1947) and the literature referred to in these papers. These two water sses are not in the main relevant to this paper and are only summarily dealt with here.

It is emphasised that diagnostic organisms are the main concern of this section of the paper, and t a description of the total plankton content of the water masses.

The Indigenous Water of the North Sea and of Other Local Areas

Russell (1935a) said that the only practical indicator of the indigenous North Sea water is *Sagitta sa*. Rees, at one time (1949), would have added the form of *Calanus* known as *C. helgolandicus* but on estigating its distribution more fully he found (1955) that this is not so. Rae and Rees (1947 added copepods *Labidocea wollastoni* and *Isias claviceps*. Williamson (1952) used *S. setosa* to indicate indigenous ter in the Irish Sea, as did Pierce and Orton (1939), but excluded *Labidocera* and *Isias*. Barnes (1950) d *S. setosa* in the Clyde area and Fraser (1937 etc.) used it to indicate the presence of indigenous water m the southern North Sea in the northern North Sea. Furnestin (1938) associated it with low salinity ter in the Gironde.

Another group which can be used is the medusae (Kramp, 1927, 1959). Care must be taken to tinguish between distributions which can be correlated with the physical or chemical environment which the organisms thrive or die and distributions which can be correlated with the natural life le of the organism. For example, *Obelia* medusae are inevitably restricted to water of coastal assoc-ons—whether oceanic coast or not—because the hydroid stage is coastal. Such an organism has an icator value of its own which can be useful if this point is kept in mind. Similar remarks can be applied the nauplii and casts of *Balanus balanoides* and to the larvae of many other coastal living Crustacea. ere are also, however, many species of neritic medusae such as *Tima, Eutonina* etc.—see the paragraphs distribution (Russell, 1953; Kramp, 1959).

The Mixed Atlantic and Shelf Water

For the northern North Sea and in the north and west Scottish areas, this subject has been covered Fraser (1937, 1939, 1952), Russell (1935 a, b, 1939) and Rae (1949); in the Irish Sea by Williamson 52) and in the English Channel by Russell (1935 a, b, 1936) and Corbin (1947). *Sagitta elegans* seems be universally acclaimed on both sides of the Atlantic, as the best single indicator species, as this cies appears to require both coastal (or bottom) influence as well as oceanic—see Fraser (1937) and rke *et al.* (1943). In an area dominated by coastal water it is thus a good indicator of an admixture oceanic water (e.g. North Sea, English Channel), but where the water is dominantly oceanic it is an icator of coastal influence (e.g. west Scottish and Irish coasts, Faroe Islands, Icelandic shelf etc.).

It is an indigenous form requiring certain mixed conditions and its use as an indicator of oceanic infl is thus of a different category from the Chaetognatha such as *S. lyra, S. maxima* and *S. serratodentata* a those other oceanic forms which indicate the presence of oceanic water on the shelf because they the selves have been transported with it. Such indicators will be more appropriately dealt with below.

The copepods used, in a comparable sense to *S. elegans,* to indicate the inflow of Atlantic water the North Sea are *Metridia lucens* and *Candacia armata* (Rae and Rees 1947). *Calanus finmarchicus* is of spec importance: when it is thriving it is rich in oil and forms a rich feeding for herring and other pela feeding fish as well as being of high value in the general productivity chain leading to good bott feeding for fish. In the North Sea *C. finmarchicus* originates partly from indigenous overwintering sto and is partly brought in from the north in early spring. Its success in the brood of the next generati in the summer, seems to depend to a large extent on the oceanic element in the water. For example, the northern North Sea a large inflow of Atlantic water in the autumn often gives rise to conditions f following spring which promote a vigorous growth of *Calanus* (see p. 20). Other organisms rich in prot associated with the "elegans" community are *Thysanoessa inermis,* various species of *Themisto, Cli limacina* and *Spiratella* (=*Limacina*) *retroversa.*

Oceanic species are transported to, and can live in, this mixed area on the shelf as long as conditi remain tolerable. Some can survive the winter but do not appear to be able to reproduce in the area e.g. *Sagitta serratodentata* and the siphonophores *Sulculeolaria* (=*Galetta*) *biloba, Dimophyes arctica* a *Physophora hydrostatica.* Others rarely survive the winter but can reproduce before the temperature fa e.g. *Salpa fusiformis, Dolioletta gegenbauri,* but the offspring also fail to survive the winter. Most mer linger in the area until they die out, in the order of their inability to withstand the conditions. Some ic of their tolerance limits is thus a help in assessing the conditions which they indicate. As already m tioned, the number of individuals present need not be dependent upon the volume of water transp The presence of the less tolerant species will, however, usually mean a greater volume transport beca the greater the inflow the less changed will the conditions be for the organisms transported in it, and t the greater the distance they can be carried and still live.

As a rough guide, the species in Table I have been divided according to three degrees of toleran Organisms in the first column are frequent invaders of the northern North Sea and occur almost ev year with the oceanic inflow. Those in column 2 are not usually present if the inflow is subnormal a will not be well represented unless it is above average strength. They are, however, fairly frequent the Faroe Channel. Those in column 3 occur only rarely in the northern North Sea, at times of p inflow, and are found in the Faroe Channel usually only as isolated specimens.

TABLE I

OCEANIC SPECIES FOUND IN THE MIXED WATER OF THE SCOTTISH SHELF

Frequent	Intermediate	Rare
COELENTERATA		
Dimophyes arctica	*Chelophyes appendiculata*	*Chuniphyes multidentata*
Lensia conoidea	*Lensia fowleri*	*Vogtia spp.*
Sulculeolaria biloba	*Hippopodius hippopus*	*Nectopyramis spp.*
Physophora hydrostatica	*Arachnactes* larvae	*Rosacea* spp.
Agalma elegans	*Staurophora mertensii*	*Nausithoe* spp.
Laodicea undulata	*Pelagia noctiluca*	*Pantachogon haeckeli*
Cosmetira pilosella		*Halicreas* sp.
Phialidium hemisphericum		*Periphylla periphylla*
		Rhopalonema velatum
CHAETOGNATHA		
Sagitta serratodentata f. tasmanica	*Sagitta maxima*	*Sagitta serratodentata f. atlantica*
	Sagitta lyra	*Sagitta hexaptera*
	Eukrohnia hamata	*Sagitta zetesios*
POLYCHAETA and NEMERTEA		
Tomopteris septentrionalis	*Nectonemertes mirabilis*	*Lagisca hubrechti*
		Vanadis formosa

LE I (*continued*)

Frequent	Intermediate	Rare
LUSCA		
lione limacina	*Clio pyramidata*	*Diacria trispinosa*
	Clio cuspidata	*Spiratella helicoides*
	Pneumodermopsis ciliata	*Spiratella helicina*
	Tracheloteuthis riseii	
	Taonidium pfefferi	
EPODA		
hincalanus nasutus	*Euchaeta hebes*	Other species of
ucalanus elongatus	*Gaetanus pileatus*	*Euchaeta*
areuchaeta norvegica	*Gaidius tenuispinus*	*Pareuchaeta* and
leuromamma robusta	*Euchirella curticaudata*	*Euchirella*
uchirella rostrata	*Metridia longa*	Most other bathypelagic species.
alanus hyperboreus	*Phaenna spinifera*	
ithona spinirostris		
IER CRUSTACEA		
hysanoessa longicaudata	*Euphausia krohni*	*Nematoscelis megalops*
ergestes arcticus	*Stylocheiron longicorne*	*Thysanopoda acutifrons*
	Brachyscelus crusculum	*Nematobrachion boopis*
	Munnopsis murrayi	*Stylocheiron elongatum*
		Vibilia spp.
		Phronima sedentaria
		Scina spp.
		Ammalopeneus elegans
I LARVAE		
Maurolicus mulleri	*Bathylagus* spp.	*Nansenia groenlandica*
Myctophum glaciale	*Fierasfer* spp.	*Stomias boa*
Gadus poutassou	*Paralepis coregonoides*	*Argyropelecus hemigymnus*

Included in this table are oceanic species from habitats ranging from warm to cold water. Those ociated with boreal influence are *Metridia longa, Calanus hyperboreus* (and to a lesser extent *Pareuchaeta egica* and *Pleuromamma robusta*), *Sagitta maxima, Eukrohnia hamata* and *Spiratella* (=*Limacina*) *helicina*. In lying this principle it is necessary to remember that boreal water may not come directly from the th but also from the cold water below the warmer north Atlantic Drift by upwelling along the edges the continental shelf. Some of these, *Calanus hyperboreus* and *Pareuchaeta norvegica* in particular, live also the cold deep water of the Norwegian Deep and can be distributed from there either by upwelling or their own vertical migration. *Dimophyes arctica* given as an indicator of boreal water (Fraser, 1952) uld now be withdrawn. Although it lives in boreal conditions it is too cosmopolitan in its oceanic ribution to have any reliable boreal significance.

The North Atlantic Drift

The North Atlantic Drift (i.e. warm water of 35‰ and over from the open Atlantic but containing e of Lusitanian origin) is the main source of inflow that affects the northern North Sea and Scottish eries generally, including those at Faroe and Iceland. Physically it has been dealt with by many lrographers, and it is the North Atlantic Central water of Cooper (1952, a, b, c). Its passage to the ttish area, through the Faroe-Shetland Channel in particular, has been described in detail by Tait 57). It has an oceanic planktonic fauna which enables it easily to be distinguished from the coastal l indigenous waters when it is transported to these areas as described on p. 5. It is not so easy to l species which can be used to define this water in contrast to other oceanic waters present in the th-east Atlantic basin. The two other water masses of significance are: first, the boreal and arctic er which, after overflowing the ridges west and east of Iceland, flows down the slope to the deeps and lerlies the other water masses, and second, the Lusitanian stream, a mixture of Gibraltar water with antic water of the Azores area, i.e. south of the North Atlantic Drift. Both of these have characteristic cies.

The fauna of the North Atlantic Drift is thus detected negatively by the presence of the cosmopolitan

oceanic species (Table II) without many of the boreal or Lusitanian forms. There will inevitably be son admixture of boreal species, slight in the main stream in the centre of the Atlantic, but becoming great towards the north and at greater depths, i.e. where the boundary is nearer, because of mixing at th interface and vertical migration of the organisms from one zone to the other. Close to the Lusitania stream there will also be boundary diffusion but it will not be so great as between the Atlantic and bore water since the areas of interface are much smaller. Some species—e.g. *Dolioletta gegenbauri, Vanad formosa* and *Rhynconerella angelini* are cosmopolitan and thus included in Table II, but are usually mo commonly found in the Lusitanian area.

TABLE II

TYPICAL COSMOPOLITAN OCEANIC SPECIES

Siphonophora
Physophora hydrostatica
Agalma elegans
Dimophyes arctica
Lensia conoidea
Chelophyes appendiculata
Sulculeolaria biloba

Medusae
Cosmetira pilosella
Laodicea undulata
Halicreas spp.
Periphylla periphylla

Mollusca
Euclio pyramidata
Euclio cuspidata
Diacria trispinosa
Pneumodermopsis ciliata
Taonidium pfefferi
Tracheloteuthis risei

Polychaeta
Travisiopsis lanceolata
Vanadis formosa
Rhynchonerella angelini
Tomopteris septentrionalis

Chaetognatha
Sagitta serratodentata f. tasmanica
Sagitta hexaptera

Thaliacea
Salpa fusiformis
Dolioletta gegenbauri

Copepoda
Rhincalanus nasutus
Eucalanus elongatus
Pleuromamma robusta
Euchirella rostrata
Euchirella curticaudata
Oithona spinirostris

Other Crustacea
Lepas spp.
Munnopsis murrayi
Brachyscelus crusulum
Meganyctiphanes norvegica
Euphausia krohni
Anchialus agilis

(4) THE LUSITANIAN STREAM

The fauna of this stream has been defined (Fraser, 1955) as "that fauna which, originating in outflow of the Mediterranean, has become modified by admixture with fauna from the area betw the Azores and the Bay of Biscay". It thus corresponds to the mixed Central and Gibraltar water

TABLE III

LUSITANIAN SPECIES IN THE SCOTTISH AREA

Siphonophora
Rosacea plicata
R. cymbiformis
Nectopyramis diomedeae
N. thetis
Bassia bassensis
Vogtia (all species)
Hippopodius hippopus
Muggiaea spp.
Eudoxoides spiralis
Chuniphyes multidentata
Lensia—all species except *L. conoidea*
Stephanomia bijuga
Velella velella

Medusae
Rhopalonema velatum
Nausithoe punctata
Pelagia noctiluca

Chaetognatha
Sagitta lyra
S. serratodentata atlantica
S. bipunctata
Krohnitta subtilis

Polychaeta
Travisiopsis lobifera
Lagisca hubrechti
Sagitella kowalewskii

Mollusca
Euclio polita
Janthina britannica

Crustacea
Nematoscelis megalops
Stylocheiron spp.
Vibilia spp.
Phronima spp.
Sapphirina spp.
Phyllosoma larvae

Thaliacea
Cyclosalpa spp.
Ritteriella spp.
Thalia democratica
Thetys vagina
Iasis zonaria
Ihlea asymmetrica
Salpa maxima
Doliolina mulleri
Doliolum nationalis

Cooper (1952a), and has originated at the depth corresponding to the sill depth of the Straits of Gibraltar, e. about 1000 metres. This water spreads out (Defant, 1955) and gradually mixes with the Atlantic ater at the interface in the process. The northern part of this fan continues to spread northwards along ie edge of the continental shelf and so plays a part in the constituent waters which affect the Scottish rea. Its importance varies from year to year. Fraser (1955) gives a list of Lusitanian indicator species to istinguish its fauna from that of the cosmopolitan species which occur in both the Lusitanian stream nd the North Atlantic Drift. This list, slightly amended, is repeated here as Table III.

A number of species that are known from the Mediterranean and perhaps the Red Sea are so far nknown from the open Atlantic. It thus might be possible to distinguish between the pure Mediterranean nd the mixed Mediterranean and Atlantic water on this basis, but as unmixed Mediterranean water is little significance to any of the Atlantic fisheries, there is probably not much point in doing so here. n the other hand, the differences between the Mediterranean and Atlantic water flowing into the Iediterranean at the surface will be of real significance in Mediterranean fisheries. Bernard (1956, 958) in particular has worked on the plankton problem associated with this interchange though largely om his own specialised subject of the phytoplankton, and he finds the Coccolithophore *C. fragilis* to e of special value in this work.

In the region of the Spanish, Portuguese and Moroccan coasts, and probably the whole west African oast to Cape of Good Hope, *Sagitta friderici* exists in the inshore waters whereas *S. bipunctata* is typical the offshore waters—see details given by Faure (1952), Furnestin (1959), Heydorn (1959) and Fraser 960b). This is reminiscent of the *S. setosa S. elegans* relationship in the North Sea and adjacent waters ut see Colman, 1959).

) The Arctic, Boreal and Cold Deep Water

Boreal, or sub-arctic, water can affect the Scottish fisheries in three ways:

a) by direct inflow, either into the area or in such a way that it dams the passage of the inflow from the Atlantic (Tait, 1949);

b) by early upwelling after overflowing the Faroe-Iceland Ridge and so entering the area with the North Atlantic Drift;

c) as the main source of the underlying deep water which occupies the floor of the whole north-east Atlantic basin; the amount of this is important in determining the amount of Atlantic water that must flow northwards to maintain the balance.

This deep water may have a mixed history and although mainly of arctic and boreal origin it will ontain also some element of Atlantic and Lusitanian water (see p. 10). Although moving it is sufficiently able, homogeneous and of long standing to allow a deep water fauna of its own to develop. The fauna this water mass is thus composite, consisting of (a) arctic and boreal epiplanktonic species, carried ver the sills, which can thrive in the continued cold but deep conditions; and (b) indigenous deep-ater species not found in cold surface water of the arctic. Some of the former exist in the deeps through-ut the whole tropical area and are found near the surface in the Antarctic—the bipolar epiplanktonic ecies of Russell (1935a).

Typical examples of the arctic and boreal (not necessarily bipolar) epiplanktonic species found in eep water in lower latitudes are given in Table IV.

Table IV

SPECIES CHARACTERISTIC OF ARCTIC OR BOREAL WATER FOUND IN LOWER LATITUDES

alanus hyperboreus	*Dimophyes arctica*	*Spiratella helicina*
Metridia longa	*Sagitta maxima*	*Sergestes arcticus*
areuchaeta norvegica	*Eukrohnia hamata*	
areuchaeta barbata		

There are also some arctic species which are carried southward with water movement but which o not appear to be able to survive even in cold deep water, probably because the depth factor is limiting.

Of these the most typical is *Oikopleura vanhöffeni; Themisto libellula* probably also belongs to this category.

Typical examples of the indigenous deep-water species are given in Table V.

TABLE V

SOME SPECIES TYPICAL OF DEEP WATER

Gaetanus pileatus	*Amalopenaeus elegans*	*Sagitta macrocephala*
Arietellus plumifer	*Hymenodora elegans*	*S. zetesios*
Pontoptilus muticus	*Boreomysis microps*	*Eukrohnia fowleri*
Centraugaptilus rattrayi	*Eucopia unguiculata*	*Nectonemertes miriabilis*
Augaptilus megalaurus	*Cyphocaris anonyx*	*Spiratella helicoides*
and many other copepods (see pp. 40-42)	*Scina* spp.	*Histioteuthis bonelliana*

A number of fish, small enough to be caught by plankton nets, can also be classified in this category such as:

Argyropelecus hemigymnus	*Cyclothone microdon*	*Paralepis coregonoides*
Stomias boa	*C. braueri*	*Bathylagus* spp.

RECORDS OF RARE OCEANIC SPECIES

Records of large-scale plankton investigations in the north-east Atlantic carried out by the Scottish Home Department, now the Department of Agriculture and Fisheries for Scotland, have added to our knowledge of the distribution of the rarer species. Lists of such records for the period 1947 to 1949 were published by the International Council for the Exploration of the Sea in their Annales Biologiques. Without such lists the records are lost in the notebooks and charts of the laboratory and it is therefore desirable to bring them up to date from time to time so that the records of major interest can be made available. Opportunity is therefore taken to do so here (see Appendix Table 1), for the years 1950 to 1956; a few records of particular interest since 1956 are included in the text.

Unless the list is to be extremely large a limit has to be set, and there is a measure of personal bias in deciding whether or not a species justifies inclusion. This inevitably means that the list cannot itself inform the reader whether species 'A' did not occur at all, or was too common to be included. It is thus necessary to include a supplementary list (Appendix Table 2) of organisms, which occurred too frequently to be included as rare, and so to bridge the gap to those which will be well recognised as common.

The size of mesh in the nets used for this investigation—26 meshes to the inch—means that small organisms are lost through the meshes; for example, copepods of a size smaller than *Calanus finmarchicus* will not be represented and are excluded from these lists. Neritic species, and the planktonic larvae of neritic species are excluded, as also are bottom-living species such as *Spadella,* and many amphipods and cumaceans that are liable to be taken in a plankton net towed near the bottom.

The organisms in this supplementary list (Appendix Table 2) are found fairly frequently over a wide range of the area investigated, usually decreasing in abundance from the Atlantic, the boreal area or Scottish and Irish west coasts, according to their origin, to the Faroe Channel and the nothern North Sea east of Shetland.

Several species given in the "rare" records (Appendix Table 1) often occurred at the same station and to save frequent repetition of the station details, the name of each organism is accompanied by one of the station numbers at which it was found.

COMMENTS ON THE ORGANISMS LISTED (Appendix Tables 1 and 2)

The precise depth of capture of any individual taken in an open net cannot be ascertained, but a study of the contents of nets from various depths in different water areas and communities soon indicates the general depth distribution of the various organisms. Such a general picture is adequate for the broad principles under consideration as they affect the fisheries, and the information is obtained with considera

ly less strain on the facilities available both at sea and in the laboratory. The hydrographic data cluding serial temperatures and salinities are not given here as they can be obtained by those interested m the Bulletin Hydrographique.

Some individual comment on the ecological significance etc. of some of the organisms listed is cessary.

Medusae

Ectopleura dumortieri is a neritic form common in the southern North Sea (Aurich, 1958). It has been luded in this list as it is quite uncommon in the northern North Sea and the records of its distribution ıy be of value. *Leuckartiara octona* is easily the most abundant of the Pandeidae and it is of wide dis- bution in the waters off the west and north of Scotland and in the northern North Sea. *Neoturris pileata* fairly common, in the Faroe Channel area in particular. *Laodicea undulata* is one of the commonest eanic medusae (*Aglantha* excepted) particularly if there is some boreal element in the water. Although quently brought to the northern North Sea its distribution is too oceanic for it to be an indicator of *gitta elegans* water, as Russell (1953) suggests, but it can itself be a very useful indicator of water move- nts. Kramp (1959) includes it in his list of neritic species but also says it is generally distributed in the lantic. In this paper the term neritic is used in a narrower sense than by Kramp.

Staurophora mertensii is normally a boreal form and is most abundant in the Faroe area. It is occasion- y found in inshore waters both in the North Sea and in the Hebridean area. Gauld (1952) reported rom the Firth of Clyde. Following Russell (1953), only one species of *Cosmetira, C. pilosella,* is recognised m this area. It is an oceanic species, most common to the south of the area frequented by *Laodicea,* d these two medusae rarely occur in the same oceanic sample. The two can thus be useful indicator ms, as they follow separate paths leading to mixing in the northern North Sea in years of big inflow. rmally *Cosmetira* tends to keep close to the Scottish coast and affects the Moray Firth area while *odicea* keeps to the north of Shetland and affects the North Sea east of 1°W.

Unless they are caught in good condition it is not easy to distinguish between *Halicreas minimum* and *liscera bigelowi,* and specimens taken out of their normal habitat are usually partially disintegrated. their distribution is essentially similar (Kramp, 1947) they have the same value and have been included gether in this list.

Previous to 1955 *Solmaris corona* was regarded as rare in the Scottish plankton but in that year it s widely distributed over a large area from the Hebrides to at least 15°W, to the Faroe Channel and the north-west of Faroe. This distribution is very similar to that given by Kramp (1959). In 1956 mbers were much reduced although it was still present as far as Shetland. In neither year was it found thin the limits of the North Sea, although it was found off the Aberdeenshire coast in 1959. Because the large number of 1955 stations at which it was reported it has been omitted from the detailed list. seems to be a species that occurs with spasmodic abundance.

The specimen of *Octophialucium* from S54/488 had 9 radial canals; similar abnormalities have been corded, see details given in Russell (1953) p. 341 as *Octocanna.*

Nausithoe globigera and *N. atlantica* are grouped together in the list.

The papers by Russell (1957, 1958) describing *Atolla vanhöffeni* and *A. parva* appeared after these ntifications were made, and it is thus possible that the records given here as *A. wyvillei* include also se species.

The record of *Tetraplatia volitans* is of particular interest so far north—see Rees and White (1957).

Although taken more recently than 1956 the opportunity is taken here to record also *Ptychogena tea* Agassiz from the surface at 60°23½′N 7°49½′W on 3rd June 1958, the identification being confirmed F. S. Russell and by P. L. Kramp to whom I am indebted. This record from the Faroe Channel now dens the distribution of this species to the 'East-Atlantic Boreal' region of Kramp (1959).

Comparing this list with those given by Kramp (1959) it is seen that many species have been known occur in the area covered by the Scottish research vessels but have not been found by them. This in lf is not surprising, especially as medusae disintegrate rapidly when carried away from their natural bitat. Many blobs of jelly occur in the plankton collections which have probably at one time been dusae but are no longer recognisable.

Siphonophora, etc

Velella has not been frequently taken in the plankton collections but there are reports of it havin been washed up in numbers at times, e.g. 1935 (Beatson, Nicol and Elton, 1936). *Physalia* has not bee found in the Scottish area. *Physophora hydrostatica* is of very wide distribution and is usually most abundan where there is an admixture of boreal water. It penetrates the northern North Sea, especially betwee November and March, to at least 57°N. It is also common in the Faroe area but less abundant west the Hebrides. *Agalma elegans* is also widespread, particularly in the summer months. It has less associatio with boreal influence than *Physphora* and it is more abundant in the open ocean west of the Hebride it also penetrates the northern North Sea to 57°N, occasionally even further, and a specimen found the Farne Is., 55°35′N, in 1955 was sent for identification from the Dove Marine Laboratory. *Nanom cara* is somewhat similarly distributed but much less commonly and perhaps associated with rath colder water. The warm-water species *N.* (*Stephanomia*) *bijuga* has not yet been found. *Marrus orthocan* (the nectophore only) has been taken but once, at the south-west entrance to the Faroe Channel; it an arctic species. *Sphaeronectes, Nectopyramis, Rosacea* and *Vogtia* are all Lusitanian species and as suc require no further comment, except to say that *Rosacea plicata* is more abundant than *R. cymbiform* and *Vogtia spinosa* more abundant than the other species of that genus. *Hippopodius* is probably also Lusitanian origin in the Scottish plankton although it has a much wider distribution than the othe It is also much more tolerant of lower temperatures and can thus survive to be carried further; it frequent reaches the entrance to the North Sea east of Shetland and sometimes survives the winter there b without becoming established. Following the nomenclature recommended by Totton (1954) *Sulculeola biloba* is the species referred to in the past as *Galetta* or *Galeolaria australis* or *G. biloba*. It is a comm oceanic form and can survive the winter in the Shetland area after having been brought in during t autumn, but does not breed there.

Lensia conoidea is the most abundant of all the siphonophores found in the Scottish area and it is thoroughly cosmopolitan oceanic species, as also is *Chelophyes appendiculats*. The other species of *Len* are all Lusitanian and are rare or very rare. *Muggiaea* spp. are not normally found in the Scottish ar although they are common in the Celtic Sea (Corbin, 1947), but in 1949 *M. atlantica* was found in t northern North Sea in November and December (Fraser, 1950). *Dimophyes arctica,* as mentioned on pa 9, is too cosmopolitan to have any value as a boreal indicator. A specimen of *Amphicaryon acaule* fr 60°23½′N, 7°49½′W on 23rd September 1958 should be recorded. The other siphonophores record are all Lusitanian, except that *Apolemia uvaria,* previously regarded as Lusitanian, now seems to ha become established in the North Sea.

Ctenophora

No Ctenophores are included in the list. The two common species *Pleurobrachia pileus* and *B. cucumis* both occur far too frequently. So far no specimens of *Hormiphora plumosa* have been identified a indeed it may not occur in the area (Liley, 1960).

Bolinopsis infundibulum does occur in the northern North Sea but this species appears to be so frag that it disintegrates into unrecognisable fragments in the ordinary rough methods of preservation adopt at sea. No specimens of *Beroe* so far taken have been determined as *B. gracilis,* see Künne (1939).

Chaetognatha

Comments on the different chaetognatha species have been given in previous papers (e.g. Fras 1952). Of the varieties of *Sagitta serratodentata* (see M.-L. Furnestin, 1953) *S.s.v. tasmanica* is the norm form while *S.s.v. atlantica* can be regarded as Lusitanian and is rare except in the south-western p of the area investigated. The environments of these two varieties were accidentally transposed in Fra (1955) but corrected in an erratum slip and also in Fraser (1957a). Furnestin considers them to rank separately valid species. One specimen of *S.s. tasmanica* taken in S.54/960 was distinctly pink in colo The name *S. zetesios* is now used as defined by David (1956). Since Ritter-Zahony's (1913) monumen work, *S. zetesios* and *S. planctonis* have been grouped together as one species under the name *S. planctor* Most workers reported this as a deep-sea species, but others considered it to be a surface species, a David has now resolved the problem by showing that the two are distinct. *S. zetesios,* the deep-wa

rm, is the only one recorded from the Scottish area. All previous records of *S. planctonis* from this area ould therefore be referred to *S. zetesios*. The occurrence of *S. bipunctata* first reported from this area in 949 has been repeated in 1953 and 1954 with a single specimen in each of these two years. *S. decipiens* as taken by "Explorer" at 59°44′N, 7°15′W on 18th March 1958 in a deep oblique haul.

Nemertea

The planktonic species are all bathypelagic, and are all rare, *Nectonemertes mirabilis* being the least re. As Coe (1945) suggests their distribution is probably cosmopolitan in deep water and they are not nfined to any geographical areas. Species known only from one ocean may be found elsewhere with dequate sampling. That two in this list are 'Pacific' species is therefore not surprising.

Polychaeta

The abundant planktonic species are *Tomopteris* (*Johnstonella*) *helgolandicus* in oceanic areas and in eas affected by an oceanic influence, *T. septentrionalis* where there is a boreal influence and *Poecilochaetus rpens* in coastal waters. Other species of *Tomopteris* are rare, as can be seen from the list. *Lagisca hubrechti* certainly the commonest of the Aphroditidae, and *Vanadis formosa* of the Alciopidae. Other recorded ecies are distinctly rare. The *Harmothoe* sp. from S.53/922 was recorded as *H. benthophila* but this may, ccording to Fauvel (1923), perhaps be the young stage of *H. longisetis*. *Travisiopsis lanceolata* is the least re of the Typhloscolecidae and is widespread even if rather uncommon, although on a few occasions vo specimens have been found in one collection. *T. lobifera* is usually more rare but was taken in 1950. *. levinseni* is a widespread but rare species; Wesenberg-Lund (1939) says it is a colourless species, but ccording to Fauvel (1916) it is yellowish when alive. The Scottish specimens were all a bright yellow hen examined in formalin after a few weeks interval, but on re-examination after about a year they as lost all colour. *Sagitella kowalevskii* occurs in the more Lusitanian areas as does *Nectochaeta caroli*. *ppadorhynchus uncinatus* and *Rhynchonerella* (*Callizona*) *angelini* may perhaps be more cosmopolitan (Støp-owitz, 1948; Tebble, 1958). Other species that might be expected to occur are those found by Dales 957) in the Bay of Biscay and those given by Muus (1956) in the 'Plankton Sheets'; especially *Lepidthenia grimaldi, Maupasia caeca, Rhynconerella gracilis* and *Greeffia celox*.

Ostracoda

The single species listed is *Gigantocypris mulleri*. Other ostracods commonly found in bathypelagic ollections are *Conchoecia haddoni, C. borealis, C. daphnoides, C. elegans,* and *Halocypris globosa,* all of which re widespread in the north-east Atlantic.

Copepoda

Great numbers of species of oceanic and bathypelagic copepods are known from the north-east tlantic see, for example, Sars (1925), With (1915), Rose (1933) and Lysholm and Nordgaard (1945). ertain of these are very abundant and are almost always found in the collections, often in numbers, hile other known species, of perhaps the same genera, are extremely rare even although their distribution similar. This phenomenon is known, of course, from most other groups of living organisms, terrestrial well as aquatic, but seems to be particularly striking in the Copepoda. Less than half the known species rge enough to have been taken by the nets used in these investigations were in fact found. Some occurred nly once or twice in the six years. On the other hand the most abundant of those species listed on p. 48 ave been taken hundreds of times each year, sometimes with large numbers on each occasion, and the hers, although less prolific, quite frequently. The really common species, of course, can reach several housand in a single collection. Opportunity may be taken here to publish records of *Bathycalanus rigidus* om the Denmark Strait on 4th May 1957 at 65°07′N 29°08′W in an oblique haul from 1400 m, and on st October 1958 at 55°28′N, 11°05′W from a similar depth.

Three copepods need special mention as the size of the specimens found exceeds the stated range uite considerably: these are *Phaenna spinifera* 2·5 mm, *Xanthocalanus greeni* 9·2 mm, and *Onchocalanus istatus* 8·5 mm. The copepod listed as *Chiridiella* spp. resembles *C. macrodactyla* Sars, but has the 1st ntennae considerably longer than the total body length; the specimen is with the British Museum.

Few parasitic copepods are found in the plankton of the open ocean although *Caligus rapax* is fairl common in the plankton from inshore waters. The most noteworthy oceanic species is *Nesippus boreal* (Steenstrup and Lütken); this is a shark parasite but the male is found not infrequently in plankto collections over deep water and seems to be distributed over a wide area of the North Atlantic fro Porcupine Bank to the Denmark Strait. Another species which might be mentioned here is *Sarcotret scopeli* Jungersen which is sometimes taken on its host *Benthosema* (=*Myctophum*) *glaciale* in the plankto nets, and at times with its own epizoic hydroid *Ichthyocodium sarcotretis* Jungersen. (Jungersen, 1911, 1913

Cirripedia

Specimens of *Lepas* are sometimes found attached to stray objects floating in the water, but mo frequently to strands of the weed *Ascophyllum nodosum*. *L. fascicularis* is the most common species, but *anatifera and L. anserifera* also occur.

Isopoda

Although according to the literature *Munnopsis oceanica* and *M. murrayi* have almost identical di tributions, only *M. murrayi* has been taken in the collections by the Scottish research ships since detail lists of oceanic plankton samples have been kept, i.e. since about 1935.

Most of the species of *Eurydice* known to occur in the area have been found, but of these *E. grimal* is certainly the most abundant.

Species of *Idothea* are usually directly associated with the coast but *I. balthica, I. pelagica* and *I. viri* have all been found at some distance from the shore, nevertheless in water with a distinctly coast influence. *I. emarginata* and *I. metallica,* however, are found in the truly oceanic water, although associat with floating clumps of *Ascophyllum*. This perhaps indicates a coastal origin, even if many months pr viously, and Naylor (1957) suggests an American origin for the British records of *I. metallica* via the Gu Stream and North Atlantic Drift.

Amphipoda

The common species are listed in Appendix Table II on p. 48. A number of other species occur b never in quantity. *Themisto libellula* is occasionally found north of Faroe, and this species with other arc forms such as *Onesimus leucopis* and *Thaumatops fabricii* also occur in 'Scotia's' collections from the Denma Strait, but not in areas affected by warmer water. The commonest bathypelagic species is *Cyphoca anonyx*. *Phronima sedentaria* is found in its gelatinous case, and each time it has been possible to ident its source it has been the salp *Iasis zonaria*. The record of *Eurisus holmi* is perhaps of special interest as is usually found much further north and in the Barents Sea. Another specimen was found on 28th Janua 1960 in an oblique haul from 1200 m at 61°21'N, 3°10'W.

Mysidacea

The large red mysid *Gnathopausia zoea* occurs occasionally, but *G. gigas* has not so far been taken Scottish research vessels. The most abundant oceanic mysid is *Erythrops erythrophthalma* but as this spec is even more common in neritic waters it is excluded from the lists. Of the listed species *Boreomysis micr* and *Eucopia unguiculata* are the commonest and often occur in the same collections. The name *E. unguicul* W-Suhm is taken as synonymous with *E. hanseni* Nouvel 1942 as used in the I.C.E.S. sheets No. 19 (Tattersall and Tattersall, 1951). These records extend the northerly known distribution of *Arachnom leuckarti, Anchialus agilis* and *Katerythrops oceanae.*

Euphausiacea

The southern species *E. krohni, N. boopis* and *N. megalops* have all occasionally been recorded in Norwegian Sea (Østvedt, 1955), as has also the bi-boreal species *T. acutifrons* (Wiborg, 1954). Spec that might have been expected in the oceanic samples taken by Scottish research vessels but which ha not so far been taken include *Bentheuphausia ambylops* and *Thysanopoda microphthalma.*

Decapoda

Adult decapoda are not usually abundant in plankton samples. *Pasiphaea sivado* is the main excepti

d although it is not often present it can be very numerous when it does occur, in such places as the rth Channel entrance to the Irish Sea. Of the bathypelagic species the commonest is *Amalopenaeus ennados*) *elegans* which is fairly general in the deep water. *Hymenodora glacialis* and *Acanthephyra* spp. cur much more rarely.

Decapod larvae are frequent, but have not been studied specifically. Phyllosoma larvae of *Palinurus garis* are not taken as frequently as might be expected, which would indicate that larvae from the main eas of abundance of *Palinurus* have already gone to the bottom before being transported so far north, d that the more northerly adults off the west Scottish coasts are not sufficiently numerous to reproduce any extent (see also Wilson, 1952). It is probable that the small numbers of *Palinurus* found off northern otland have been derived from transported larvae, and that they are not self-maintaining stocks; ambs-Lyche (1958) holds the same opinion about specimens found in Norwegian waters. Lewis (1951) tes that larval development requires about six months, during which time larvae can be carried oo miles in the Gulf Stream.

Mollusca

Several species of pteropods are listed on p. 48 as being too common to be included in the list, but these only *Spiratella retroversa* occurs in great abundance. It may occasionally reach about 1 litre in a minutes' haul with a 1 metre net, over the continental shelf in areas where the oceanic influence is stinct. The other species mentioned there and those recorded as rare are all oceanic, but with a wide nge from *Euclio limacina,* which is the most tolerant and often thrives and breeds in the northern North a, to species like *Peraclis moluccensis,* which is in this area very strictly an oceanic exotic. *P. tricantha* also curred in Scottish collections in 1948 but not during the period 1950-56. The cold water species *iratella helicina* has not been as common as expected from data given in the literature, even in areas here there is distinct evidence of arctic or boreal water. It was never taken in the Scottish collections ring the period under consideration here. *Euclio polita* can be regarded as a Lusitanian species, as can *nthina*. Shells of *Janthina* have been reported washed up on the western coasts of Scotland (Beatson, col and Elton, 1936) but have rarely been found in plankton collections.

The heteropod *Carinaria lamarcki* was found in both 1952 and 1953 further north than in previously blished records. *Atlanta* and *Firoloida* have been found off the south-west of Ireland but they have not t been found in Scottish plankton collections, although occasional dead shells have been taken as far rth as the western entrance to the Faroe Channel. On 11th May 1959 a large specimen of *Pterotrachea tata* was also taken there, 59°44′N, 7°15′W, in a deep haul from 1000 m.

The most abundant cephalopods are the young stages of the commoner pelagic (as distinct from nktonic) species which occur in the oceanic areas, particularly members of the family Gonatidae. nall Cranchidae are also quite frequent, particularly *Tracheloteuthis* (*Brachioteuthis*) *riseii* and *Taonidium fferi,* and they can add their quota to the indicator value of the community. Records of less common cies include *Desmoteuthis hyperboreus,* of which there were three during the years 1950-56, and *Histio-this bonelliana,* which was found once only. Stephen (1944) gives details of earlier records, and the parent recent increase in the numbers of *Taonidium pfefferi* is of interest.

Tunicata

A short section on the appendicularian fauna and its ecological significance is given on p. 37 in the pendix.

A general picture of the occurrence of Thaliacea in the waters affecting the Scottish area was given Fraser (1949); as this was supplemented in 1952 and in 1955 it does not require much comment re. In this group, more than in any other, emphasis must be drawn to the distinction between those lividuals which have themselves been transported into the area and those which have been reproduced thin the area because exceptionally high temperature conditions permitted it. Where large numbers original individuals occur, and have been together a long time, they tend to denude the water of ytoplankton and therefore also of the food supply of copepods and other zooplankton and so exist relatively pure communities. Recently reproduced individuals have not had time to do this so that arms in the central North Sea in exceptional years are found with the normal communities of the area

(see Cattley, 1950). The transport of great volumes of denuded water into the late summer herri fishing grounds might have repercussions on the fishery, and indeed if repeated would affect the botto fauna and so also the food supply of demersal fish. The regeneration of nutrients in this water, and mixing with indigenous water during the winter months does, however, appear to stimulate good grow of plankton the following spring (see p. 21).

Salpa fusiformis is the commonest species of salp and is of cosmopolitan oceanic distribution temperate and warm water. It occurs in the Scottish area almost every year, sometimes in small numbe only, but sometimes in dense swarms, e.g. in particular 1920, 1921, 1925 and 1954. *Ihlea asymmetrica* also at times very common, but this species is less tolerant than *S. fusiformis* and it has a delicate test. is thus frequently very disintegrated when found in the Scottish area and is usually represented by "nucle only (i.e. the concentrated ball containing the stomach etc.) but occasionally with enough of the fra mentary test to show the characteristic muscle bands confirming its identity (Fraser, 1949; Farran, 190 In 1953, however, many specimens were alive when caught and in excellent condition, and in this ye also *Cyclosalpa virgula* and *Ritteriella picteti* were found, both first records from so far north (Fraser 195 *Iasis zonaria* occurs only in isolated instances in this area and has never been abundant. It has a durab test in both solitary and aggregate forms and thus gets carried in recognisable form for long distanc *Thalia democratica,* probably the most abundant salp in the world, is not sufficiently tolerant to withsta the conditions so far north as the Scottish area and, although it occurs off the western end of the Engli Channel and south-west of Ireland, it rarely penetrates further north. Until 1958 only occasional spe mens have been taken by the Scottish research vessels in the Porcupine Bank area and in the Continuo Recorder survey they were caught further north over the deep water west of Scotland in July 1954 a in September 1955 (Rae, 1956, 1957a). Apstein (1894) and Herdman (1888), however, both record it occurring in immense shoals off the Hebrides towards the end of the last century. Similar shoals we not recorded there again until 1958, when *Thalia* thrived in great numbers in a band extending fr the west of Ireland to the Butt of Lewis.

Cyclosalpa bakeri was recorded off the north of Scotland in 1932 and 1937 (Fraser, 1949) and a lar *Thetys vagina* was taken in a herring net off Wick in 1929 (Thompson, 1948). Neither of these has be found in the years dealt with here, but a single specimen of *Thetys* was taken on 2nd October 1958 53°20′N, 14 40°W. A solitary *Pegea confoederata* was taken at 20 m on 13th November 1958, from 59°24 3°45′W.

Of the doliolids, *Dolioletta gegenbauri* is certainly the most abundant, and in fact almost the or species found in the Scottish area and extending frequently into the North Sea (Fraser, 1949; Lucas, 193 Cattley, 1950). In the open oceanic area it is usually present as the variety '*tritonis*', but less so in the sm gonozoids reproduced within the area, thus confirming Garstang's (1933) opinion that *D. gegenba* and *D. tritonis* are the same species. *D. nationalis,* like *Thalia,* is found off the entrance to the Engli Channel but rarely penetrates into the Scottish area. Rae (1956) recorded some specimens mixed wi *D. gegenbauri* in 1954 west of the Hebrides. This species and *D. mülleri* are quoted by Fraser (1955) Lusitanian and occurring off the English Channel in 1953, but *D. mülleri* has not so far been found furth north.

Pisces

The eggs, larvae and post-larvae of commercial fishes are not dealt with in this paper.

Plankton nets are far from ideal for catching adult pelagic or bathypelagic fish or their later you stages, so that records are likely to be spasmodic and of little practical value. With such frequent sampli they do, however, catch occasional specimens and so widen the known distribution; certain records interest are therefore listed. Opportunity may be taken to add two 1957 records of *Diplolychnus bif* Regan and Trewavas from 61°51′N 23°20′W on 9th April 1957, and from 61°51′N 23°25′W, alm the same place, on 4th July 1957. *Antennarius radiosus* Garman was found at 54°10′N 12°10′W on 5 October 1958 (see Palmer, G. *Ann. Mag. nat. Hist.*, Ser. 13, **3**, 149-151).

It is, perhaps, worthy of note that although there are several species of *Argyropelecus* with fai similar distributions only *A. hemigymnus* has so far been found by Scottish research vessels, and, althou *Benthosema* (=*Myctophum*) *glaciale* is very common, *Electrona* (=*Myctophum*) *arcticum* is much more sca

nd other species seem to be rarities. The fish listed as *Nansenia* spp. are mostly *N. groenlandica* but at ast one (S.55/723) is believed to be a new species and is to be dealt with by the British Museum. Lepto-ephali must be very abundant in the North Atlantic yet surprisingly few are caught by the 1 metre lankton nets; the Corbin net with its greater 'D' shaped size of about 3 metre head rope caught up to per $\frac{1}{4}$ hour haul (at 57°38′N 15°14′W, 31/7/56), at 10 fm during the night. Proportionally, this must ean that fish such as *Benthosema glaciale* and the young pelagic stages of *Gadus poutassou*, of which some undreds are taken yearly in the plankton nets, must be very abundant indeed (see p. 27).

FAUNISTIC RELATIONSHIPS AND THE FISHERIES

The planktonic species which may be used to indicate the presence of the various water masses have lready been noted (p. 6). The presence of these organisms can be a valuable label, although they may ot themselves have more than a minute significance in the ecological systems involved, and therefore o the fisheries. As mentioned below, however, certain of them do have very pronounced direct effects, ut it is the general fauna associated with these labels, and its environment, that has the principal gnificance.

Research in recent years has more and more emphasised the complicated subtleties of the require-ents of different organisms in the phytoplankton (e.g. Provasoli, McLaughlin and Droop, 1957) and e resultant effect on the ecological relationships in the sea (e.g. Lucas, 1956; Wilson, 1951; Johnston, 955; Collier, Ray and Wilson, 1956; Bentley, 1958, 1960). The major component physical factors, the asonal temperature and light variations and the dominant currents follow a similar general pattern om year to year so that there is always the basic annual picture of biological succession. The relatively naller changes in volume transport and the constituent proportions of water masses of different origins re, however, big enough to make distinct differences to the plankton production and so to affect the sheries. These changes may be merely seasonal, annual or even long-term trends. The phytoplankton dependent on the organic constituents, often produced by bacteria, as well as on the inorganic nutrient lts and trace elements. It appears that many organisms produce metabolites which may affect the owth of their neighbours, thus resulting in a chain of succession of dominance, although Talling (1957) oes not consider this adequately established. The succession of phytoplankton occurs, however, and could sult in changes in succession of zooplankton; as these too may complicate their environment with xcretions and secretions the whole plankton production could be affected. Specific phytoplankton and ooplankton composition can also be important as the potential food value of the different species may ary, partly because of their chemical constituents, but also because their shape or other physical factors an make them unavailable. Certain phytoplankton organisms, for example, are not suitable food for me planktonic grazing species (Gibor, 1956).

Each water mass, though "labelled" by a few indicator species that may be of greater or lesser nportance in the eco-system, has a characteristic fauna often typified by the abundance and condition many species which are also found in other water masses but in different numbers or in different roportions. The richest production of crustaceous zooplankton in the area round the British Isles—id thus the potential fertility of this area for pelagic fish and, via the bottom fauna, probably also for emersal fish—is not found in any one of the incoming water masses, but where these meet and mix ith the local waters. This is no doubt due in part to the different waters having been impoverished of fferent chemical constituents (both organic and inorganic) during their various histories so that mixing ay replenish the fertility of each. Upwelling of nutrient-rich deep water and land drainage each play eir important part, adding nutrients, trace elements and metabolites to the euphotic zone in the areas mixing.

It is thus that the water labelled 'elegans water' contains the richest zooplankton of the water asses around the British Isles, and the greatest crops there of copepods such as *Calanus finmarchicus*, *eudocalanus elongatus, Centropages typicus, Temora longicornis, Acartia clausi* and *A. longiremis, Candacia mata, Oithona spinirostris* and *O. similis* etc., euphausids such as *Thysanoessa inermis, T. raschii* and *Nycti-anes couchii*, decapod larvae, amphipods, cladocerans etc., all of which are rich in protein content and

often oil content. This rich crop of zooplankton is usually maintained in spite of the abundant predator fauna that often goes with it. It is preyed upon by the pelagic fish and the planktonic stages of demersa fish and either directly, or indirectly via disintegration, it forms the food of the bottom fauna specie which are the major source of food for the demersal fish—this will be dealt with more fully later.

In the oceanic waters, with which this paper is mainly concerned, the zooplankton communitie are not themselves usually as rich as the mixed 'elegans' community. An exception is in the rich borea oceanic conditions of the Norwegian Sea (Wiborg, 1955), only the fringe of which is in the area considere here. This is the area north of the Faroe-Iceland Ridge, where temperature conditions are not normall conducive to the formation of stratified water and there is thus general intermixing of the Atlantic an the boreal water masses, in contrast to the area further south where currents and the continental slope are responsible for upwelling. In nearly all this northern area there is a great abundance of oily plankton including *Calanus*, *Meganyctiphanes*, etc., which is of great significance to the Atlantic herring while feedin in this area; further, this rich planktonic fauna with the plankton-feeding capelin and herring is directl or indirectly responsible for the great cod fisheries there. Conditions are similar still further north Jaschnov (1939) states that in the south-western part of the Barents Sea *Calanus* forms by weight 74-91% of the total plankton. Lednev (1958) states that "variation in the inflow of Atlantic water into the Baren Sea influences the fishery; the rate at which the fish migrate eastward, the distribution and their con centration in certain areas are all affected". Baranenkova (1960) demonstrates a definite relation betwee an increase in the warm water and the numerical strength of O+ cod and haddock in the Barents Sea

The warm surface water of the Atlantic inflow is naturally relatively poor in plankton. Ryther an Yentsch (1958) show that productivity at the surface decreases in a seaward direction over the America continental shelf and that the annual rate of carbon fixation is even less in the north central Sargass Sea than in the most seaward of the Shelf stations; in Long Island Sound, by comparison, the valu given is almost five times as great. The surface waters, as they approach the British Isles, contain suc organisms as *Agalma, Arachnactes, Beroe* etc. which can often be seen from the ship's side, but species o good feeding value are rare. The inflow is richer in the sub-surface layers as is typical of most warm waters (Jespersen, 1935; Leavitt, 1935, 1938; Clarke, 1940; Bernard, 1955b). Even as near the surfac as 10 metres—the depth chosen to run the Hardy Continuous Recorder—the fauna is much richer containing an abundance of siphonophores (including in particular *Lensia conoidea, Chelophyes appen diculata* and *Sulculeolaria biloba*), medusae such as *Laodicea, Cosmetira, Turris* etc., *Salpa fusiformis, Doliolet gegenbauri* and a fair crustaceous element, particularly *Acartia longiremis, Oithona spinirostris* and patches o *Temora longicornis* and *Centropages hamatus*. Included also are a few of those other organisms which are mor abundant at deeper levels (100-300 m), such as *Pareuchaeta norvegica, Rhincalanus nasutus, Eucalanus elongatu Pleuromamma robusta, Gaetanus pileatus, Clione limacina, Clio pyramidata, Tomopteris helgolandicus, T. septe trionalis*, several species of *Conchoecia* (Ostracoda) and of fish such as myctophids and post-larval *Gad poutassou, Stomias, Paralepis* etc.

Calanus finmarchicus is not usually abundant in this Atlantic plankton at any depth, but swarms i great numbers both on its northern edge, i.e. the interface with the boreal water, and also along i southern edge against and on the continental shelf, i.e. the interface with the indigenous water. Bot these *Calanus*-rich areas are of great importance to the fertility of the fishing grounds. The former affec the Icelandic, Faroese, Norwegian and Bear Island areas as well as the northern North Sea, where th fringe may be brought in along the edge of the main inflow east of Shetland. The second affects all th Scottish fishing grounds, from Stanton Bank to the Minch, the shelf area north of Scotland and west o Orkney and Shetland, the Shetland herring fishing grounds and the area to the north-east of the Aberdeen shire coast fished by the Fraserburgh and Peterhead fleets. Dense patches of *Spiratella* (=*Limacina*) als occur with *Calanus* in this band and feeding on this organism by herring gives the familiar 'black gu condition in contrast to the 'red gut' when *Calanus* predominates. This shelf plankton is normally at i densest in May and June, supplying rich feeding to the north-east herring grounds; but its constitutio and distribution are more probably functions of the balance between the physical, chemical and biologic components of the water off the edge of the continental shelf in early spring rather than those of th northern North Sea in May and June. However, this water, rich in food material arrives on the fishin grounds in late spring to mix with, rather than replace entirely, the local water in this part of the northe

orth Sea. Just as mixing off the shelf produces conditions for excellent growth of *Calanus* so also does ixing in the area of the northern North Sea itself (Fraser, 1937; Rees, 1957) but in order to have the ght conditions there, in time for the spring reproduction and growth of *Calanus* which have over-intered there at stage V, the mixing must have occurred earlier. Tait (1937) emphasises that the hydro-raphic conditions in the Faroe-Shetland Channel determine those in the northern North Sea, and it ould thus seem that the oceanic inflow of the previous autumn and winter leaves a legacy conducive to ch growth the following spring, and indeed might continue to be effective for a much longer period. his could account for the trend of increased *Calanus* in the spring in the North Sea from 1947 to 1955 Glover, 1957, Fig. 7) in association with an increased Atlantic inflow.

Planktonic conditions in this part of the northern North Sea in summer, which are of direct im-ortance in the herring fisheries, may thus depend on either local growth affected by the inflow of the revious year, or the richness of the zooplankton brought in by the mixed inflow of the current year, r both. It must be emphasised again that this richness is associated with mixing of an oceanic element nd a local or inshore water and not with the inflow itself. Thus, where the oceanic water itself enters ie northern North Sea in a relatively unmixed inflow, conditions will not be right for a rich zooplankton opulation there until later, after mixing has occurred and there has been time for the succession of rowth. Pelagic fish such as herring do not appear to be found in normal quantity when such unmixed ceanic conditions occur. This could be due to the fish leaving the area because of lack of food, to distaste f the water itself (possibly of the same substance which is causing the difference in specific content of lankton) or to the presence of salps or other oceanic species. However this may be, an unmixed influx f oceanic plankton during the herring season would be expected to cause an early end to the Shetland shery, and indeed the evidence since 1920 strongly suggests that this is so.

The distribution of the main concentrations of different plankton communities in the Shetland area, efore the close of the fishery, can be shown to have a positive and direct effect on the distribution of the erring there. In July 1958 "Scotia" investigated this factor. The herring shoals were fairly widely attered during the first half of July, as was shown by the echograms, in the areas east of Fair Isle, 20 iles east of Sumburgh (South Shetland), 30-50 miles east of Yell (North Shetland), 10 miles north-west Flugga and between Foula and Shetland. These traces were nowhere particularly dense and large ume traces were few, so this distribution is fully consistent with the spotty distribution of the shoals as und by the commercial vessels. By the second half of July the herring traces were very much more ncentrated to the south-east and east of Fair Isle and commercial vessels from Shetland were making xcellent catches. At this time echometer traces from other areas were similar to those of early July, where indicating the concentrations found near Fair Isle; few boats were working elsewhere.

During the first half of July the plankton pattern showed four distinct communities; (1) dominant nd abundant *Calanus*, only in the Fair Isle area from about 2°15′W to 0°15′E; (2) mixed *Calanus* with uphausid furcillia and other zooplankton but also with small jellies, *Cosmetira* and *Laodicea* in the area uth of Fair Isle, and with *Pleurobrachia* east of Shetland; (3) *Calanus* with abundant *Spiratella* in the area rth and west of Shetland within 25-30 miles of the coast, and with a slight leakage through to the east Shetland via the north of Fair Isle, i.e. north of the first mentioned community; (4) outside these mmunities, in the oceanic area, dense quantities of *Salpa fusiformis*. By the second half of July the ankton pattern had changed. Salps had still not penetrated round the north of Shetland to the east le, but the *Calanus-Spiratella* patch had extended round Flugga and southwards into the area east of etland as far as 60°N. The *Calanus-Pleurobrachia* community has thus been pushed rather further east-ards in this area but *Calanus* with jellyfish were still present south of the *Calanus* patch near Fair Isle

It would seem that herring in Shetland waters were fairly widely distributed in early July 1958, t that the shoals were in local patches and thus difficult to fish economically except in the Fair Isle ea where catches improved during July. This later concentration in the Fair Isle area coincided with e only area of abundant *Calanus* that was also free of small jellies. It occurred in a relatively stationary tch of water where temperature conditions were more or less homogeneous throughout the water depth, though a thermocline was well marked elsewhere. Thus it seemed that herring aggregated in this area, ough it is debatable whether this was due to a positive attraction or to the avoidance of conditions ewhere.

That the distribution, and therefore the availability for catching, of herring and other pelagic fish can be associated with the production and abundance of their food has long been known—see, for example, the following papers and the references contained therein: Pearcy (1885), Savage and Hardy (1935), Hardy, Henderson, Lucas and Fraser (1936), Fridriksson (1944), Einarsson (1951), Sette (1955), Cushing (1955 a, b, 1956, 1957), Blackburn (1957), Glover (1957), Jakobsson (1958). The relationship is not always a simple one (Lucas, 1936; Manteufel, 1939; Fridriksson, 1944; Cushing, 1956; Glover 1957), because of the grazing effect of the predators on the prey, but basically it is true to say that the stocks of fish will normally be found where conditions have enabled the food supply to be most plentiful and that they will move out of areas where it is scarce or conditions are otherwise unacceptable. In extremes, great quantities of salps filter the phytoplankton content almost completely as fast as it can be produced over areas off the coasts of the British Isles of as much as 20,000 square miles, so depriving crustaceous zooplankton of their food supply. This community of jelly appears to be little used as food by fish (Thompson, 1942; Fraser, 1949), although in September 1958 cod were reported to be feeding on salps west of Orkney (Fraser, 1960a). In comparison with the richer fat and protein content of crustacea etc. they contain little that can eventually form the food of the bottom-living animals; from this point of view they could have a serious effect on fisheries. That potential effect is subsequently offset, however by the quickening of the regenerative process of returning nutrients to the water after death and so increasing the plankton production the following spring. The actual presence of such masses of chains of salps, which are by no means confined to the surface (Fraser, 1949), could itself be a physical repellent to pelagic fish. Glover (1957) stresses the importance of associating plankton conditions with shoaling habits and thus with the availability for capture by the fisheries. Salps and conditions associated with salps may have an effect of this type as well as acting as a repellent. This effect of oceanic water is not only felt by adult fish; for example, Huntsman (1920) put forward evidence (p. 332) to show that the 'wrong type' of water may prevent the development of fish eggs and larvae in the Atlantic west of Cape Breton. Rae (1957b) infers from a study of plankton, wind and haddock broods in the North Sea that environmental conditions which may be wind-induced are in a large measure responsible for the success or failure of the broods. This is quite distinct from the actual transport of the larvae by wind-induced currents to unsuitable areas, e.g. Saville (1956).

Corlett (1958) has shown a clear relationship between the plankton of the western Barents Sea and the year-class strength of the Arcto-Norwegian cod, even though this was not found for cod eggs and larvae by Wiborg (1957). That the brood strength is associated with environmental conditions in the widest sense—which affect plankton abundance—is evident from Ottestad (1960) who has shown a relationship between the brood strength of cod at Lofoten and the growth of pine trees in the vicinity.

Morris (1956) found that larval fish associated with mixed conditions were easier to rear in aquarium conditions than those associated with a particular water mass. The relative abundance of larval fish in 'elegans' water, as a typical indicator of mixed conditions as compared with 'setosa' water (Russell, 1940) may thus be more fundamental than the abundance of a suitable food supply. This relationship is not confined to the English Channel but is shown also in the northern North Sea where the boundary between these two types of water is influenced by the inflow from the Atlantic round the north of Scotland and Shetland. Fraser (1961) for example divided the records of plankton samples taken in the northern North Sea by Scottish research vessels according to their *Sagitta* content. He showed that the numbers of larval fish were greater in the mixed water characterised by the presence of *S. elegans* than when this species was replaced by *S. setosa* or absent. This relationship did not apply to early stages of fish eggs, and this suggests that, whatever the reason may be, the mixed water is better for the survival of larvae rather than for egg production. The better survival in 'elegans water' has presumably nothing to do with the actual presence of *S. elegans* and, indeed, as this is a predatory species the effect of its actual presence might be just the reverse. Because the mortality rate of larval fish is dependent upon the combination of a number of factors, the direct relationship between the numbers of North Sea recruits of various fish to the commercial stocks would not be expected to correlate directly with the numbers of *Sagitta elegans* or with the proportion of the North Sea occupied by this species. Haddock, for instance, spawn in the area in the northern North Sea where *S. elegans* is normally typical and an extension of 'setosa water' northwards but not reaching the haddock spawning grounds would have no effect on the survival of the

ood. Nevertheless Glover and Barnes (1960) state " . . . the summer months during the period 1947-51 were characterised by typical neritic and North Sea plankton; from 1952 to 1954 there was an vasion of indicators of the mixture of Atlantic oceanic and shelf water; from 1955 to 1958 the shelf ankton dominated the fishing grounds with a scarcity of extreme neritic and oceanic plankton." An sessment of the haddock broods over this period shows 1946 to 1950 to be rather poor, 1951 to 1955 od and 1956 to 1957 extremely bad, and 1958 rather better. Saville (1959) reached a similar conclusion. sing plankton indicators to define the conditions he stressed the importance of mixed conditions, neither ritic nor oceanic, on the success of the broods of haddock in the northern North Sea. Summarising his able IX it is seen that if less than 25% of the haddock spawning area was free from oceanic and neritic ater the index of the survival of the haddock brood was rated at 0·7; 25-50%, 1·4; 51-75%, 4·4; and er 75% free, 6·8.

The differences in survival between these types of water, as shown in the English Channel and orth Sea, is all the more important when it is realised that the mixed conditions which favour the fish d their food also favour the production of predatory species. The small coelenterates are the chief enders, especially *Aglantha,* but also *Cosmetira, Laodicea,* other medusae and the siphonophores.

Ctenophores and chaetognaths are also serious predators. *Pleurobrachia* can almost denude great acts of inshore water of its zooplankton and young fish content (Foerster, 1948 p. 60; Lebour, 1922, 23; Bigelow, 1910, 1924; Kuhl, 1932; Kamshilov, 1959). In the North Sea area it is at its densest autumn and less likely to affect the spring fish larvae. *Aurelia,* while in its early stages in the spring, likely to be a serious predator on young fish, but in its later stages it feeds only on the zooplankton. he large jellyfish, particularly *Aurelia* and *Cyanea* have another important effect in that they can exist such numbers that fishing in Faroese waters can be spoilt by choking the trawls. Similar serious results cur in the Gulf of Finland (Hela, 1951). Lucas and Henderson (1936) note that good catches of herring e not usually taken where jellyfish abound. Swarms of predatory species (except *Aglantha*) are not so mmon in the oceanic waters as on the shelf but their abundance in mixed shelf water is linked with the st biological history of the incoming water.

Apart from the Chaetognatha, which are important food organisms for herring, few of the predatory ecies are themselves useful as food, and this particularly applies to the Coelenterata. *Pleurobrachia* is t usually considered a valuable source of food but is occasionally eaten, probably only if nothing else available—a not infrequent condition when they swarm. Records of *Pleurobrachia* as food of *Acanthias* d *Cyclopterus* are given by Mortensen (1912), of *Mola* by Bigelow (1924), of West Greenland cod by ansen (1949) and of mackerel by Scott (1924). *Beroe,* however, is eaten frequently by cod but probably s by haddock (Kiselev, 1960) and also by *Cyanea* (Plotnikova, unpublished). Trawl-caught haddock m the east Scottish coast in June 1958 were sent to the Marine Laboratory at Aberdeen as their machs contained a most unusual, orange-coloured food. They had been feeding on the siphonophore *alma elegans* with numerous *Calanus* and euphausids entangled in it—it was probably the clumps of the tangled crustacea that attracted the haddock as food, rather than the *Agalma.* However, even if these edators are themselves seldom eaten, they will add to the fertility of the water by excretion and in due urse by regeneration of nutrients after death. Indeed Davidson and Huntsman (1926) consider that the oducts of disintegrating *Aurelia* contribute significantly to the later diatom production. Sudden release nutrients from decaying organisms (Graham, 1954) or from land drainage can produce the conditions ding to the notorious 'red-tides' (see, for example, Fish and Cobb, 1954) which in some areas, but not Scottish waters, have a profound effect on local fisheries and indeed, economically, on a wider scale.

Thus the changing planktonic environment will not affect all fish broods or the abundance of the ferent predatory species in the plankton in the same way; for example the different distributions of *itta elegans* and *S. setosa* and other species of chaetognaths, medusae and siphonophores. Alterations environment thus affect the larval and post-larval stages of fish and their brood survival. This may be lirect effect of the transport of larvae (see below) but may also occur through the resultant planktonic nges. Food of the right type must be available in sufficient quantity after the larvae hatch (Hjort, 26) whether there is a "critical period" in their early stages or not (Marr, 1956). Shelbourne (1957a) s suggested that plaice larvae cannot withstand starvation at the period of yolk sac absorption without erely upsetting their osmotic regulation.

Different fish larvae hatch at different times of the year and have different food requirements for instance post-larval herring feed chiefly on copepods and molluscan larvae (Lebour, 1924; Hardy 1924; Ogilvie, 1927; Bowers and Williamson, 1951; Bhattacharyya, 1957) while plaice larvae (Shel bourne, 1957b) and lemon sole larvae (unpublished Scottish investigations) feed mostly on Appendicularia *Oikopleura* is also taken occasionally in masses by adult haddock (Fraser, 1957b).

Although it seems certain that the succession of plankton species and the identity and abundance o the dominant forms are dependent upon the past history of the water, both hydrographically and biologic ally, the complicated processes that control these features are very far from being adequately understood It is possible to state with confidence that mixing of the water masses gives rise to conditions of bette production of crustaceous zooplankton and thus perhaps better feeding for fish. It is not yet possible t forecast the final outcome of fluctuations in the environment; nor is it possible to state that because o certain factors the diminished food supply or the incidence of predators will or will not become seriou elements in young fish mortalities. Another planktonic cause of fish mortality in the egg or larval stage not yet properly assessed, is parasitism by dinoflagellates; for example sardine eggs infected by *Ichthy odinium chabelaudi* (Hollande and Cachon, 1952) seem to develop normally, but the young fish which ar infected soon die after hatching. In May 1949 many eggs of cod, saithe and ling found by "Scotia" a 63°44′N 21°35′W near the south-west coast of Iceland were heavily infected by spores in the peri vitelline space. Herring eggs in the Clyde spawning area at Ballantrae Bank in the spring of 1959 wer found to be infected by a dinoflagellate similar to *Ichthyodinium.*

A further very important relationship between the plankton conditions and the fisheries concern the survival and distribution of the bottom fauna, particularly the crustaceans, molluscs and polychaete and the sandeels and other small fish which will eventually become the food of the demersal fish. It should be again emphasised that the right conditions (see Wilson, 1951; Wilson and Armstrong, 1952, 1954 for the growth of the bottom fauna, both as adults in situ and in the planktonic developmental stages are dependent upon the biological history of the various water masses that have been mixed and brough into the area where the animals of the bottom fauna are feeding and spawning. Edmondson (1957 points out in this connection that phytoplankton may be much more extensively used as food of such organisms than, because of rapid digestion, the examination of gut content would suggest.

Blacker (1957) has shown that the distribution of benthic animals in the Svalbard south of Spitz bergen is dependent on hydrographic conditions and that stenothermic species in particular can be used to indicate these. The bottom fauna is influenced by the greatly increased average influx of Atlantic water into this area in recent years, and while warmer conditions can play a great part in the extinction of established Arctic species, irrespective of their life history, it is only those Atlantic species with a plank tonic stage that can spread rapidly northwards to become established in the new conditions.

Finally, mention should be made of two other possible effects of planktonic environments on fisheries First, although it is no longer generally accepted that certain animals can use dissolved substances a food as suggested by Pütter (1909), there is support for feeding on leptopel (Fox, Isaacs and Corcoran 1952; Morris, 1955). The amount and type of leptopel is of course largely dependent upon the planktonic history of the water, and Gillbricht (1959) says "Das Zooplankton lebt also offenbar von der Zerfalls produktion einer in ihre Masse längst verschwundenen Phytoplanktonbevolkerung". Secondly, Listo (1956) has shown that the maximum bacterial population in the skin of skate and lemon sole follows th phytoplankton outbursts, and Georgala (1958) found a similar pattern on cod, the supposed connectio being the increase in bacteria in the sea with the decomposition of the phytoplankton.

A number of general papers on the environmental hydrographic effects on fisheries have been written emphasising one aspect or another, but are not quoted above or in the following sections. Of these th recent ones include those by Cooper (1952, a, b, c, 1955b), Hachey (1955), Boden and Kampa (1953 Lee (1952), La Fond (1954, 1955) which in turn quote many others. That many of these hydrographic effects operate through the plankton seems certain and some examples have been quoted. This pape emphasises that these plankton changes may be dependent on conditions outside the fishing ground themselves.

THE TRANSPORT OF PLANKTONIC STAGES OF FISH

The eggs of most fish and the early stages after hatching are planktonic, so that at these stages they e themselves part of the planktonic environment and subject to the various changes that occur there. ome of the effects of biological changes have already been dealt with in the previous section. The direct ysical effect of the environment also has its profound effect on survival (Huntsman, 1920; Sund, 24; Hjort, 1926).

Walford (1938) discussed the effects of currents on the distribution and survival of the eggs and rvae of haddock on Georges Bank. Sette (1943) investigated the survival of eggs and larvae of mackerel d Chase (1955) discussed wind and temperature relations with brood strength of haddock in the same ea. Saville (1956) has considered similar problems at Faroe and also (1959) in the northern North Sea, d Wiborg (1957) for the Arcto-Norwegian cod stock. Carruthers, Lawford, Veley and Parrish (1951) ggested that the brood strength of haddock in the North Sea could be correlated with wind conditions. as Rae (1957b) says, the main causative factor in this correlation is the wind induced environmental nditions prior to spawning, it is still probable that wind induced surface currents will have significant fects on the distribution of the planktonic stages.

These, and similar papers show that brood survival varies according to a complexity of factors and at no single factor, biological, hydrographical or meteorological, provides a simple answer.

The hydrography of the fishing grounds in situ is not the concern of this paper and these planktonic lationships with hydrography are mentioned in passing. It is, however, the concern of this paper to nsider certain fish larvae in oceanic plankton and to refer to their physical movements as they drift th the accompanying invertebrate fauna over the areas off the Scottish coasts. Schmidt (1909) discussed is problem over the wider area between Iceland and Spain and dealt with the distribution and spawning nditions of seventeen species of Gadidae in great detail. Fraser (1958) discussed the drift of planktonic eanic fry off the west and north-west of the British Isles from their spawning places to possible areas of ttlement, giving approximate distances and duration of transit. He found, as far as the young of com- ercial demersal fish are concerned, that only Rockall Bank and the Faroe plateau of the oceanic banks this area can be considered with certainty as self-supporting; Porcupine Bank is doubtfully so, while ere is little chance of young fish from spawnings on the other banks remaining to grow into adults on e same banks. Stocks on these must be maintained largely by migration of demersal stages of fish or om drift of larvae from other banks as fry drifted from these will not be entirely lost, though it is certain at many will. From Porcupine Bank larvae might eventually be able to settle on the Irish continental elf or on Stanton Bank; from Rockall to other outer banks or on the Scottish continental shelf, and from ousy, Bill Bailey and Faroe Banks on the Faroe plateau or the Scottish continental shelf in the neigh- ourhood of Shetland or Orkney. This is confirmed to some extent by the presence of small larval haddock ken in oceanic plankton collections over deep water, i.e. away from their spawning grounds, and by the esence of larger young fish at about the limits of the pelagic phase—up to 11 cm—taken in pelagic awls in the Faroe Shetland Channel and over banks such as Bill Bailey Bank where it seems most likely that the fry could remain for several months. Henderson (1954) also reports gadoids, other than *poutassou* and other deep-water forms, 30-50 miles beyond the 100 fathom (183 m) line. Clearly the lative success or failure of such fish will depend greatly on variations in the local currents.

The larvae of oceanic fish also drift with the plankton but apart from hake and ling few have as yet uch commercial significance to Scottish or other fisheries, except as part of the food cycle. One of the ost important of these is *Gadus poutassou*, the blue whiting, which forms one of the dominant foods of e hake (Hickling, 1928). It is largely pelagic, even in the adult stage in the middle and upper layers er great depths, and it spawns beyond the 1000 metre line in relatively warmer waters (Schmidt, 1909). hmidt also states that the populations of *G. poutassou* at Iceland, at Faroe, in the northern North Sea, the Norwegian Sea and in other northern waters are the result of larval planktonic drift, presumably lowed by a pelagic migration. Henderson (1957) describes the main abundance of the larvae in the ea west of the British Isles as occurring in April and May over the deep water east of Rockall and tending north-east to the Faroe Shetland Channel and towards the Faroe-Iceland Ridge. He considers

it likely that the Barents Sea (Boldovsky, 1939) and the Polar Basin populations have originated from separate but unlocated spawning. Schmidt (op. cit.) points out that the larvae of *G. poutassou* were ofte associated with *Salpa fusiformis,* and Fraser (1958) also found this, pointing out that the final dispersa of the larvae could probably be depicted from the final distribution of the salps, bearing in mind that th larvae would become less planktonic as they grew older and that the salps could reproduce in trans given suitable conditions. This would mean that, in 1955 at least, the larvae could be carried well int the North Sea, to the Norwegian fjords, to south-west Iceland and Jan Mayen, but not into the Baren Sea. This agrees with the normal distribution of the older fish and supports Henderson's suggestion of separate spawning for the Barents Sea stock (see also p. 28).

Fraser also deals briefly with the part played by larval drift in the distribution of the hake, anothe species with deep-water spawning. He says ". . . in this species the planktonic stage is shorter so tha although the first general distribution is likely to follow that of *G. poutassou* the final dispersal is much le dependent upon drift than on migration and is therefore less widespread. There is no evidence of hak spawning at Faroe or Iceland, but there is a spring spawning off the Irish coast and a summer spawnin off the north of Scotland (Hickling 1928). Following the lead of *G. poutassou* there should be scope for th larvae to be drifted to the south-west of Iceland, but because of the shorter planktonic stage young hak have never been found there although older fish have been taken on rare occasions (Saemundsson 1949). It can be assumed that these were adult migrants. Hake are, however, occasionally abundan in the deep water east of Shetland; as the distances are so much less, these could possibly be associate with the north Scottish spawning grounds, but the situation is complicated by adult migrations, an Hickling (1928) considers them to belong to a self-contained stock."

Fraser also considers that the drift of planktonic fry of haddock and saithe is responsible for th small stocks of these species in Iberian waters, south of their normal range, where there is no evidence o spawning.

OCEANIC PLANKTON, FISH AND ECHO TRACES

The problem of organisms which are responsible for oceanic scattering layers, whether deep or no has been considerably debated. Whilst most authors consider small fish, especially those with swi bladders, to be at least an important source of the echo reflections there is a wide range of opinion abou how far small planktonic organisms can be responsible. Cushing, Lee and Richardson (1956) have bee able to associate echoes with zooplankton at a density of 25 organisms per litre, and phytoplankton o 100,000 cells per litre. Most other authors mention the possibilities of planktonic organisms being i part the cause but emphasize that fish, especially the swim bladders, and gas bubbles associated wit the fish are the main cause: e.g. Parrish and Craig (1951), Marshall (1951), Tucker (1951), Hersey an Backus (1954), Kanwisher and Volknam (1955), Backus and Barnes (1957), Weston (1958). There ar also instances of large planktonic or pelagic invertebrates being considered as the source; e.g. euphausio (Moore, 1950), heteropods (Blackburn, 1956), squid and shrimps (Smith, 1954) and penacid prawn (Gordon and Ingle, 1956). Authors dealing with the commercial side of echo detection have, of cours emphasised the importance of fish themselves—e.g. Hodgson (1950), Burd and Lee (1951), J. Furnesti (1953), Capart (1955), Craig (1955), Cushing and Richardson (1955 a and b) and many others (s Hodgson and Fridriksson, 1955), though few of these deal with oceanic traces.

Whether or not the smaller planktonic organisms will produce an echo depends on their characte and also on the frequency, sensitivity and other characteristics of the echosounder in use. Some attemp were made from the Scottish research vessel "Scotia" in June and July 1955 to locate scattering strat in the upper water layers of the north-east Atlantic west and north-west of the British Isles, and t identify the organisms concerned. The machine in this instance was the Kelvin Hughes MS 24G operatin at 30 K/cs. No difficulty was experienced in locating traces. In addition to the usual "plume" trac characteristic of the northern North Sea ribbon traces, both diffuse and well-defined, were found in th oceanic area. Plankton nets towed above, at, and below the depths of both these kinds of traces frequentl showed the absence of any correlation between the normal organisms of the plankton and the trace

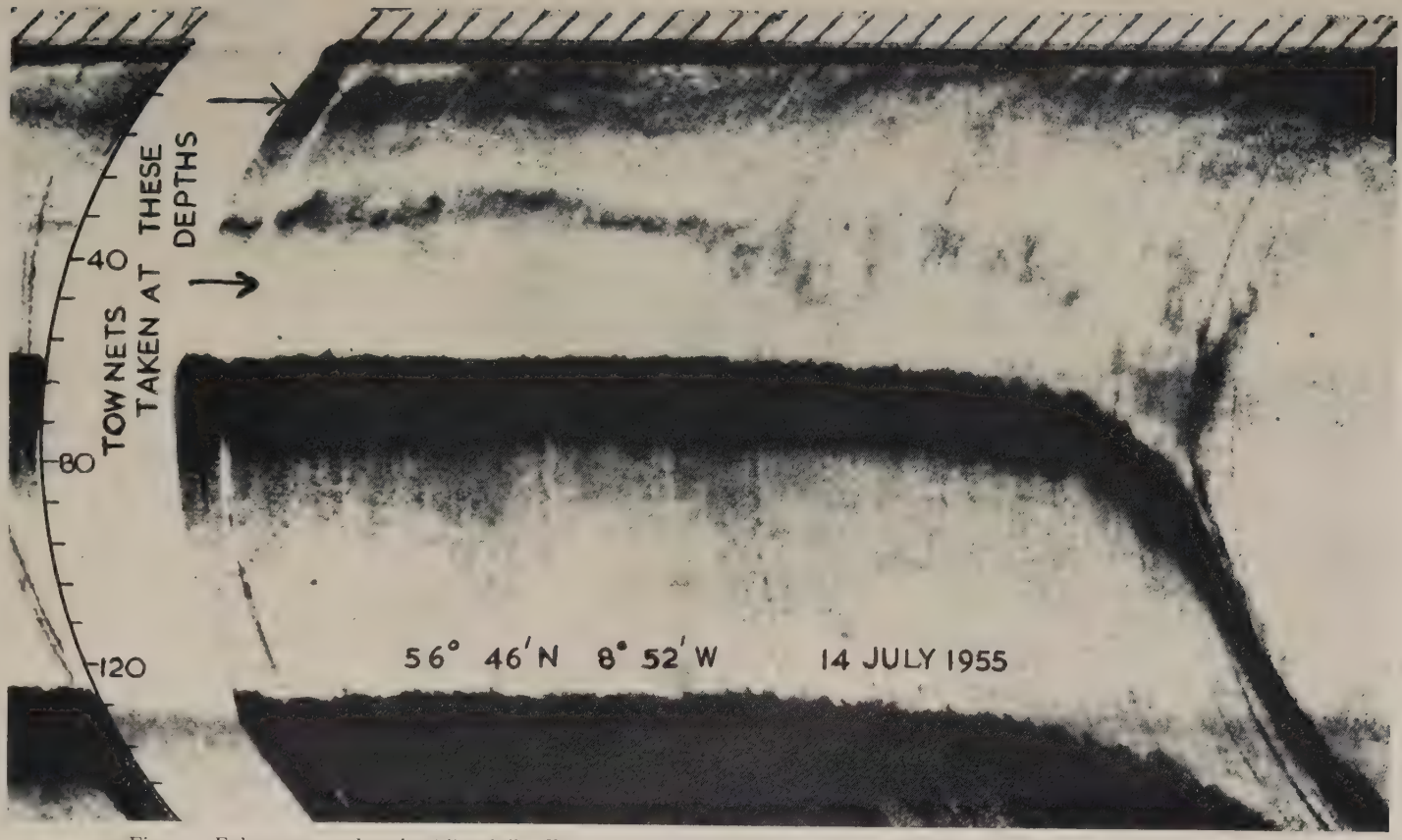

Fig. 2 Echo trace taken by "Scotia" off the west coast of Scotland at 56°46′N, 8°52′W, on 14th July, 1955. The time markings are at two minute intervals and the depth markings at 8 fm. Townets (26 meshes to the inch) were taken at the depths indicated by the arrows. The upper one in the dense trace contained very sparse plankton, the lower one below the trace contained abundant *Calanus* and *Spiratella*. Note the trace upwelling at the edge of the shelf and overflowing on to it at about 30 fm depth. (The dense trace at about 125 fm is a "double echo" of the bottom).

example in Figure 2 which shows a dense ribbon trace over the shelf and continuing over the deep ter. The trace was about 10 fm thick, and at 23-33 fm depth, at 56°46′N 8°52′W. A one metre townet mesh) towed at the depth of the trace (and it could hardly fail to be at the right place for most of tow) revealed very little plankton indeed and practically no *Calanus*. A similar net towed quite initely below the trace at the same time contained dense quantities of *Calanus* and *Spiratella* (=*Limacina*). is collection has been estimated to contain about a quarter of a million *Calanus*. Towed for $\frac{1}{4}$ hour at proximately 2 knots this would represent, under good filtration conditions, only about 1 *Calanus* in litres. This is so very short of the artificial figure of 25 organisms per litre used experimentally by shing and Richardson (1955a) that it is not surprising that no traces were recorded from the *Calanus* pulation, and it does not mean that traces cannot be obtained from zooplankton. It does mean, how- r, that the very dense and obvious traces were not caused by *Calanus* or any similar organism. The ure also illustrates a column of echoes arising at the edge of the continental shelf and drifting over it ow the main trace—i.e. a trace associated with upwelling.

Diffuse traces were recorded in areas of abundant *Pleurobrachia* in the northern North Sea but not en much denser concentrations of salps occurred in the oceanic area. As these two organisms are gely of a similar consistency and the salps have in addition a dense nucleus, it does not seem reasonable attribute traces to *Pleurobrachia* if salps cannot produce similar effects. On no occasion during the vey were abundant zooplankton organisms confined to so narrow a depth stratum as that shown by ribbon trace.

A commercial Icelandic pelagic trawl, fitted with a codend of $\frac{1}{4}$ in. mesh, was used to sample the ces. This revealed the presence of young fish, both by day and by night, in the areas of diffuse traces, ecially in the northern North Sea where haddock and whiting of 5-11 cm in length were taken—i.e. agic stages too active to be caught by the townets and too small to be taken by commercial gear. ung lemon soles and other small fish were also taken in the plankton nets in the areas of diffuse traces. ese observations show no evidence of diurnal vertical migration by the larger young fish which were t as abundant at noon as at midnight at depths of 8-30 fathoms. At sensitivity '4' on the "Kingfisher" fitted to "Scotia" in July 1955 these young fish caused interference patterns on the cathode ray screen only about $\frac{1}{2}$ to 1 in. in the Fladen area. At night these fish were joined by larger fish such as whiting to 25 cm which caused interference patterns of $1\frac{1}{2}$ to 2 in. at the same sensitivity setting.

The Icelandic pelagic trawl with small mesh was also used to investigate dense ribbons traces found the oceanic regions. Two main behaviour patterns were exhibited by these ribbon traces; one showed le evidence of diurnal migration and from the catches was evidently due to the young of *Gadus poutassou* d the other, which only appeared a short time before midnight and disappeared with the dawn, was ributed to a mixture of oceanic fish, particularly *Benthosema glaciale* with smaller numbers of *Myctophum ctatum, Maurolicus mulleri, Stomias boa* and *Gonostoma*. Further evidence that these echoes were probably e to fish is provided by the appreciable increase in their depth that occurred when the ship stopped, obably owing to the various ship's noises frightening the fish. Deepenings of as much as 30 fm in 10 nutes were recorded, indicating that this was caused by organisms capable of individual active move- nts.

Euphausids were not abundant during the trip and the evidence for and against their causing traces s inconclusive; their scarcity, however, suggests that they were not the cause of the traces recorded ring the survey in 1955. Of special interest were the hauls taken on Rosemary Knoll on 20th July ere prior to midnight the echo traces appeared in two layers—one at 15-20 fm and one at 35-40 fm. e deeper trace sampled just prior to midnight, produced about 80 *G. poutassou* with some scopelids one haul. The lower trace gradually ascended until the two traces coalesced; a second haul in this xed trace at about 15 fm also contained about 80 *G. poutassou* with some scopelids, but in addition penaeid prawns, *Funchalia woodwardi*, of 14-16 cm (see Gordon and Ingle, 1956, for full details, with opy of the echo trace).

The 1955 "Scotia" traces believed to be due to the young stages of *G. poutassou* occurred only to the th of 57°N, east of Rockall. They extended north across Rosemary Knoll, Faroe Bank, thence to the st of Faroe as far as the Faroe-Iceland Ridge and also into the south side of the Faroe-Shetland Channel the immediate north-west of Shetland beyond the 100 fm line. This is similar to the picture given by

Schmidt (1909) and Henderson (1957) (quoted in the previous section, p. 26). The scopelid traces occurr only in the southern part of the section investigated, south of about 59°30′N.

Henderson says (p. 180) of *G. poutassou*—"Further one cannot disregard the possibility that t widely distributed species, which is by no means the smallest of the gadoids, may yet become exploit commercially. . . ." He refers to the adult stages, but a fishery for the young stages is not beyond t realms of possibility as the numbers of these young stages in the upper oceanic layers in summer must enormous. Similar remarks also apply to the scopelids. One of the objects of this cruise in 1955 was t preliminary investigation of the industrial potential of these small fish. A possible fishery for young *G. poutassou* would be confined to the May-July period but would be available throughout the 24 hou Although a scopelid fishery would extend over a longer period of the year as they are adult fish and r therefore so seasonal in their appearance, it would be limited to the hours of darkness which are short during the summer. In spite of the great numbers of young *G. poutassou* which were evidently the area it must be admitted that the catches taken by "Scotia" with the gear then available did not rea commercial proportions. To ensure the success of such a fishery would undoubtedly need, as in oth fisheries, gear specially designed for the purpose, presumably with a very small mesh and wide gap With the appropriate gear there may well be real possibility in poutassou fisheries, for both young a adults, a possibility that might be further improved if accompanied by a method of inducing the fish congregate in local shoals.

SUMMARY

This paper attempts to clarify our knowledge of the plankton communities in the oceanic wat around the British Isles and their relationship to the fisheries.

The basic current systems are mentioned as the distribution of the communities is dependent up these currents.

Five types of plankton community are recognised, viz:

the indigenous North Sea water,
mixed Atlantic Shelf water,
the North Atlantic Drift,
the Lusitanian stream,
the Arctic, boreal and cold deep water.

Each of these has its own characteristic fauna and an attempt has been made to typify them.

The data gathered over a period of years inevitably includes records that extend the previou known distribution of various species. Those of special interest that would otherwise be lost in the reco books of the laboratory have now been brought together to make them available to specialists in th particular fields.

Ecological, taxonomic and other comments are given on the species included in these lists. A sh section on the distribution of Appendiculata summarises the unpublished work of Miss S. T. Linds who worked as Carnegie scholar in Aberdeen from 1927 to 1930.

The effect of these plankton communities and changes in the communities on the fisheries is de with, partly by a review of known effects in various parts of the world, and partly by an assessment the probable effects in the Scottish area. These act in the following ways.

1. Growth promoting or inhibitory factors due to changes in plankton in turn affect productiv and specific composition.
2. The mixing of water masses with differing organic and chemical content and differing faun results in an increased abundance of zooplankton, which is directly the food of pelagic fish a indirectly of demersal fish.
3. The distribution of pelagic fish, and therefore to some extent of their availability for capture at times directly influenced by their food supply in the plankton.
4. Certain organisms, such as salps and ctenophores may have a repellent effect on migrat pelagic fish. This may be due to an actual positive repellent or to these organisms eating out t

basic food supply of the fish, but the products of their disintegration may have beneficial effects on future productivity.

5. Planktonic predators and parasites, with a planktonic phase or origin, cause mortality in fish eggs and so affect the brood survival.
6. Plankton is the food of larval and post-larval fish and the sufficiency and suitability of the organisms present also affects fish brood survival.
7. The distribution and abundance of the bottom fauna as food for demersal fish is to a large extent based on the distribution and survival of the planktonic larval stages.
8. The organic and bacterial content of the sea water is dependent upon plankton production and disintegration, and this in turn has its effects on the fisheries.

Changes in the oceanic plankton being brought into the fishing grounds on the continental shelf partly, and sometimes largely, responsible for these effects.

The eggs and planktonic stages of fish are dealt with as plankton organisms and a section is devoted their distribution by currents in the oceanic areas around the British Isles with an indication of how se can be responsible for the existence of self-supporting fish populations on some isolated banks.

The final section deals with echo traces in the oceanic area and their possible origin in small plankic fish. Evidence is given to show that concentrations of *Calanus* and other small invertebrate species curring in their natural numbers in the open sea do not produce echoes on the model of echo-sounder d. Some of the oceanic fish may exist in sufficient numbers to make a fishery but a profitable method catching them has not so far been devised.

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APPENDIX

Distribution of Appendiculata in Scottish Waters

This section is based on the investigations of Sheila T. Lindsay who worked on the subject in Aberdeen veen 1927 and 1930 as holder of a Carnegie Scholarship. The results of her work were never written for publication but this paper provides an opportunity to publish a resumé of the more important ures. (Further details may be obtained if required by application to the Marine Laboratory, Aberdeen).

Three abundant species were found; *Oikopleura dioica* Fol, *O. labradoriensis* Lohmann, and *Fritillaria alis* Lohmann. Only two other species were found in these particular years; *O. fusiformis* Fol, and *F. ucida* Busch, although a particular look out was kept for other species which might reasonably be ected to occur. Previous and more recent work show that *O. vanhoffeni* Lohmann is a cold water cies which has been recorded from near Shetland (Lohmann 1911) and in the Faroe area (Fraser Saville 1949). *Appendicularia sicula* Fol and *Fritillaria venusta* Lohmann are warm water species occasion- recorded from the North Sea (Lohmann 1911). Other species occurring in the north-west Atlantic, regarded by Bückmann (1945) as likely to occur in the Scottish area, are *O. parva* Lohmann, *F. ilis* Lohmann, *F. tenella* Lohmann and possibly *F. aberrans* Lohmann.

Oikpleura dioica

This species is widely distributed in warm and particularly in temperate waters but is not found in arctic. It occurs within wide ranges of both temperature and salinity and is generally regarded as ng more abundant in inshore waters than in the open ocean (e.g., Berrill, 1950; Forneris, 1957). ertheless a study of the seasonal extension of its distribution in the North Sea shows that it is either ught into the area each year from the open ocean, or that it is at least associated with the inflow. reafter its multiplication leads to the largest numbers generally being found in the inshore waters t becomes distributed throughout the central North Sea. The data from the years in question confirm impression that this species was absent or scarce in January and February, presumably after the vious year's stock had died down. The spring influx of oceanic or mixed water via the north of Shetland the Orkney passages brought with it the conditions that favoured the growth of *O. dioica* as well ntroducing it. By May and June the mixed water, and so therefore the distribution of *O. dioica*, had nded into the whole northern North Sea roughly north of a line from about the Firth of Forth to gen excepting the inner extremities of the Firth of Forth and Moray Firth. The next period, July and gust showed a very marked increase in numbers in the firths, (large numbers in the Moray Firth, ll numbers in the Firth of Forth) although it was still apparently absent off the north-east English st. In September and October numbers in the central North Sea were still fairly large, the densest centrations being then found in the Firth of Forth and off the Danish coast. Numbers in the Shetland a were much reduced but the Orkney area was still densely populated. There were obvious signs of ntegration in November and December.

This pattern of extension fits in with the hydrographic conditions in the North Sea and by rapid oduction during May to September, when egg formation was apparent in the ovary, the pattern vn would soon develop. *O. dioica,* like *Sagitta elegans* and *Metridia lucens* can thus be regarded in the hern North Sea generally as an indicator of mixed oceanic and coastal water though at a later stage ixing as the season progresses. This seems true also off the west coast of Scotland; where the mixture ceanic water with shelf water occurs *O. dioica* achieves its greatest abundance. *O. dioica* does, however, ear to have an indigenous population in the southern North Sea, as it is present on the plaice spawning nds in the Southern Bight in spring (Shelbourne, 1953).

Oikopleura labradoriensis

According to Lohmann (1900) this species is indigenous in cold and mixed waters and occurs in ndance up to 70°N. It has a wide distribution in the colder parts of the North Atlantic, but occasionally rs at temperatures up to 11·6°C—though Essenberg (1926) reports specimens from southern California emperatures between 12·6°-13°C, and in her Table 2 Forneris (1957) gives it a range of −1·36 to 0°C. It occurs in the northern North Sea but not in the Baltic, Kattegat, English Channel, or Irish

Sea, and this investigation also shows it to be absent, in the surface waters at least, off the west Scotti coast. Its numbers in the North Sea are small compared with *O. dioica* and it is most common fro March to June, thereafter being replaced by *O. dioica* until the late autumn.

From the apparent absence of *O. labradoriensis* in the Faroe-Shetland Channel during the seas of major inflow, and from its general distribution in a large part of the northern North Sea even at i period of least abundance, it must be assumed that an indigenous population lives in the North S and that some of the summer brood survive to maintain it. There is a suggestion that this populati may be augmented by inflow east of Shetland at a time when this might include an admixture of co water. Unlike *O. dioica*, however, there is no sign of inflow via the Orkney passage, where the curre has its origin from the upper layers of the west coast area which is free from boreal influence. Its co water preference is shown by fairly high numbers south of Faroe (but north of the Wyville Thoms Ridge) where a colder south-flowing current underlies the Atlantic stream.

Its main breeding period is May and from this brood come the high summer concentrations of t northern North Sea. During the period investigated some years were more productive of *O. labradorien* than others; 1930 was a peak year, 1928 least productive and 1927 and 1929 intermediate. This is perha relevant in the light of the observations of Fraser (1949) showing that 1928 was a peak year for the wa water indicator species *Dolioletta gegenbauri*, although the actual surface temperatures in the area off t Scottish coast (Smed, 1953) indicated slightly subnormal temperatures in 1928 and in 1929 and slight above normal in 1927 and 1930. The two warm-water Appendiculata referred to below also occurr only in 1928.

Fritillaria borealis

This species is generally known as a cold-water species occurring in abundance in arctic a antarctic seas, but it also occurs in the Mediterranean and off the coast of southern California (Berri 1950). It has been divided into sub-species (see Lohmann and Bückmann, 1926 and Bückmann, 194 and of these *F. b. acuta* occurs in the cold and temperate waters and *F. b. truncata* in warm water. Bo are liable to be found in the Scottish area (Bückmann, 1945) but the data in this paper refer only *F. b. acuta*. *F. borealis* was never abundant in the area south of a line approximately from the Ang Scottish border to southern Norway and it is perhaps significant that this is similar to the general divisi between the communities of *Sagitta elegans* and *S. setosa* (Fraser, 1952). *F. borealis*, like *S. elegans* showe tendency to be less common in the more open ocean of the Faroe-Shetland Channel, and an ocea origin cannot be regarded as contributing materially to the North Sea stocks.

Fritillaria reached its greatest numbers—except in certain localities—in March and April, genera dying down in the summer although it never disappeared. When conditions are suitable it can reprod in quantity and very high figures were recorded in the north Minch in March and April and in the Fi of Forth in June and July. Reproduction appears to take place at any season of the year and ripen gonads were frequently seen in this material in each month from March to October.

Other Species

During 1928, but not in any other year from 1927 to 1930, two southern species, *Oikpleura fusifor* Fol and *Fritillaria pellucida*, not indigenous to the Scottish area, were taken, but they did not long persi

O. fusiformis is typical of warm seas but has been reported from the North Sea (Lohmann, 191 Bückmann, 1926); presumably it occurs with other Lusitanian species which arrive there from time time in late summer.

F. pellucida is also typical of warm water and, so far as has been ascertained, these records, numer in early September, are the only ones for the Scottish area, although it is abundant in the Mediterrane and in warm and temperate parts of the Atlantic south of 42°N. The distribution of each of these spec in the Scottish area is restricted, mainly because they are much less tolerant to local conditions, so t only exceptionally, as in 1928, do they survive to reach the Faroe-Shetland Channel and thence North Sea.

APPENDIX TABLES

Table I

LIST OF RECORDS OF RARE OCEANIC SPECIES FOUND BY SCOTTISH RESEARCH VESSELS, 1950-56, AND BY H.M.S. CHALLENGER, APRIL-JUNE, 1953.

Station details are given at the end of the table and are preceded by a letter, 'E' denoting "Explorer" and "Scotia", and a number indicating the year; stations preceded by the symbol 'Ch' refer to samples taken by M.S. *Challenger* off the entrance to the English Channel in 1953 and reported by Fraser (1955): Ch.53/15-19th ril; Ch.53b/25-28th May; Ch.53c/16-23rd June.

edusae

purena ophiogaster Haeckel, E55/544.
topleura dumortieri (van Beneden), E50/491, S53/694, 925, S55/846.
nclea costata Gegenbaur, E52/1197, S52/886.
tablema vesicarium A. Agassiz, S56/296.
ndea rubra Bigelow, E50/135.
thothiara murrayi Günther, S53/922, 929, S55/936, S56/271.
aranna rotunda (Q. & G.), S53/1698.
romatonema rubrum Fewkes, S50/847, S51/312, S54/810, S56/321.
elicertum octocostatum (M. Sars), E52/1247, 1248.
pleurosoma typicum Boeck, S53/586.
ychogena lactea Agassiz, (1958, see p. 13).
tophialucium funeraria (Q. & G.), S54/488, S55/233?
lobonema sericeum Vanhöffen, S50/855, 867, S51/374, S54/960, S56/321.
ntachogon haekeli Maas, E50/135, 141, S50/847, 855, 874, S51/312, 363, 364, 371, 374, 375, 604, 688, 695, E52/1196, 1197, 1308, 1314, S53/922, 934, 953, S54/453, 461, 469, 488, 516, 891, 904, 954, 959, 987, S55/727, 840, E56/594, S56/296.
alicreas minimum Fewkes or *Haliscera bigelowi* Kramp S50/394, 847, 855, 949, S51/275, 363, 364, 375, 688, E52/1162, 1200, 1305, 1314, S52/533, 1377, S53/922, 934, 953, 1611, S54/453, 469, 479, 482, 557, 847, 960, S55/682, 727, 832, 840, 972, E56/586, 594, S56/262, 296, 335, 368.
gina citrea Eschscholtz, S53/557.
gina spp? S54/879, S55/846.
ginura grimaldii Maas, S54/954.
riphylla periphylla Peron and Lesueur, S50/783, 847, 855, 859, 874, S51/363, 364, 375, E52/1162, 1197, 1308, S53/26, 549, 934, 1597, S54/453, 488, 516, 557, 563, 590, 595, 855, 891, 904, 960, S55/672, 840, E56/594, S56/296, 335.
ausithoe spp. S50/847, 867, 874, 937, S51/129, 275, 304, 363, 364, 371, 374, 375, 604, 688, 695, E52/1161, 1308, S53/934, 953, 1637, S55/840, E56/474, S56/377.
olla wyvillei Haeckel, S50/847, S53/555, 1646, 1648, S55/841, 949, E56/474.
traplatia volitans Busch, E52/1305.

phonophora

lella velella (L.), S51/358, E52/1193, 1198, 1203, Ch53/10, S54/906, 979, 989.
arrus orthocanna (Kramp), S51/688.
haeronectes gracilis (Claus), S54/935, 947, S55/9.
nphicaryon acaule Chun, (1958, see text).
ectopyramis spinosa (Sears), S51/363, 371.
ectopyramis thetis Bigelow, E52/1305, S54/516, 954, S55/721, S56/271, 296, 335.
ectopyramis diomedea Bigelow, S51/363, S55/948.
osacea cymbiformis Delle Chaije, Ch53/7, S53/209, 2277, S54/987, 1338.
osacea plicata (Q. & G.), E50/141, 767, S50/855, 867, 874, S51/275, 363, 364, 695, E52/1339, S52/1280, Ch53/9, S53/555, 934, 953, S54/453, 469, 961, S55/41, 69, 936, 948, 972, E56/459, 586, 594, S56/262, 265, 271, 296, 335, 368, 382.
gtia glabra Bigelow, S51/364, E52/1305, S53/953, S54/488, 913, 991, E56/466, 471, S56/296.
gtia spinosa Haeckel, E50/135, 138, S50/949, S52/1377, 1497, S53/548, 1648, S54/879, 987, 991, 1181, 1188, S55/721, 948, 972, E56/586, S56/278, 321, 382.
gtia pentacantha Kölliker, S51/371, E52/1305, S52/1497, S55/840, 948, E56/601.
gtia serrata Moser, S56/262, 321, 335.

Lensia cossack Totton, S51/337, 377, S54/479.
Lensia fowleri (Bigelow), S51/377, E52/1342, S53/925, S54/456, 696, 935, 949, 953, 960, 986, 988, 1183, 1187, 1188, 1395, 1396, S55/702, 843, 936, E56/567, 586.
Lensia multicristata (Moser), S51/364.
Lensia achilles Totton, S51/371, 374, 375, 385.
Lensia lelouveteau Totton, S51/363.
Lensia ajax Totton, S51/374.
Eudoxoides spiralis (Bigelow), S51/357, Ch53/4, 5, 6, 7, 8, 9, 10, 11, Ch53b/1, 3, 6, Ch53c/6, 8, 10, 12, 13, S53/939, 945, S54/935, 959, S55/66, 201.
Thalassophyes crystallina Moser, S51/375.
Heteropyramis maculata Moser, S51/363.
Bassia bassensis (Q. & G.), E52/1198, Ch53/5, 7, 9, 10, 11, Ch53b/1, 3, Ch53c/8, 10, 13, S53/1661, 1667, 1697, E54/1608, S54/936, 959, 961, 988, S56/315, 328, 330, 337.
Apolemia uvaria (Lamarck), S53/1646, 1648, 1654, 1980, 1990, 1991, 2238, 2274, 2277.

Chaetognatha

Sagitta lyra Krohn, S50/775, 783, 845, 867, 874, 922, 927, 932, 937, E51/1417, 1574, S51/364, 374, 377, E52/1161, 1165, 1174, 1195, 1196, 1197, 1212, 1280, 1305, 1311, 1339, S52/1287, 1365, Ch53/7, 8, 9, 10, S53/1597, 1646, 1648, 2288, 2537, S54/879, 935, 949, 953, 960, S55/840, 843, 948, E56/586, 596, S56/371.
Sagitta hexaptera d'Orb., S51/374, E52/1161, S53/929, 2288, S54/482, 949.
Sagitta bipunctata Q. & G., S53/953, S54/379.
Sagitta macrocephala Fowler, E50/135, S50/400, 847, 855, 874, S51/312, 363, 371, 374, 672, 679, 688, E52/1196, S54/453, 456, 469, 488, 849, S55/727.
Sagitta decipiens Fowler (1958, see p. 15).
Eukrohnia fowleri R.Z., E50/135, S50/847, 855, E51/1579, S51/364, 374, 375, 672, 688, E52/1200, 1314, S53/1597, S54/353, 453, 456, 879, 960, S55/727, 840, E56/474, S56/262, 321.
Krohnitta subtilis (Grassi), E50/138, S54/456.

Nemertea

Nectonemertes mirabilis Verrill, S50/855, S51/363, 375, S54/488, 879, 954.
Nectonemertes pelagica Cravens and Heath, S55/672.
Pelagonemertes brinkmanni Coe, S54/954.

Polychaeta

Harmathoe sp. S53/922.
Lagisca hubrechti (McIntosh), E50/767, S50/783, 847, 855, 874, S51/364, 374, 672, 695, 851, E52/1305, 1318, S53/953, S54/453, 456, 469, 479, 847, 855, 879, 960, S55/233, 840, E56/594, S56/271, 296, 321.
Nectochaeta caroli Fauvel, S54/935.
Lepadorhynchus uncinatus Fauvel, S53/922.
Tomopteris nisseni Rosa, S54/453, 469, S55/971, E56/586.
Tomopteris kerfsteini Greeff, S54/557.
Tomopteris cavalli Rosa, S54/954, S55/363, 545, E56/472.
Tomopteris krampi Wesenberg Lund, S56/321.
Travisiopsis lanceolata Southern, S51/594, S52/825, S53/935, S54/482, 488, 595, 954, S56/296.
Travisiopsis levinseni Southern, S50/855, S51/364, S54/488, S55/233.
Travisiopsis lobifera Levinsen, E50/135, 767, S50/394, 783, 847, 855, 867, S51/364.
Sagitella kowalewskii Wagner, S51/375, E52/1317, Ch53/6, 12, S54/960.
Vanadis formosa Claparède, E50/135, 138, S51/363, 364, 368, 371, 376, 377, 385, 570, 602, E52/1161, 1165, 1200, S52/838, 1502, Ch53/9, S53/298, S54/696, 855, 873, 949, 953, 954, 986, 987, 988, 1396.
Rhynchonerella angelini (Kinberg), S52/1280, 1281, Ch53/10, S54/456.

Ostracoda

Gigantocypris mülleri Skogsberg, S51/672, E52/1314, S54/453.

Copepoda

Megacalanus longicornis (Sars), S51/363, 371, 695, S54/453, 987, S55/727, E56/474.
Megacalanus princeps (Brady), S51/364.
Bathycalanus richardi Sars, E50/135, S50/847, 855, S51/374, 375, E52/1196, S54/482, 516, S55/727.
Bathycalanus rigidus Sars (1957, 1958, see p. 15).
Eucalanus crassus Giesbr., S50/949, Ch53/5, 8, 10, S53/1697, 2059, S54/456, 935, 949, 953, 960, 961, 962, 981, 986, 1181, 1184, 1188.

ocalanus validus Sars, S54/855.
ocalanus caudatus Sars, 256/296.
diopsis rostrata Sars, S53/944.
diopsis multiserrata Sars, E56/474.
inopsis similis Sars, S53/922.
idius poppei Giesbr., S53/934.
idiella sp. S55/963.
lius brevispinus (Sars),
lius brevicaudatus Sars, S52/141, S55/936, 941, 971, E56/586, S56/296, 382.
anus kruppi Giesbr., S54/488, 516, 855, 891, 904, 954, 987, S56/262, 296, 335.
anus miles Giesbr., S50/867, 874, 949, S51/275, E52/1311, S52/1377, S54/954, S55/832, 941.
anus curvicornis Sars, S50/874, S51/695.
anus latifrons Sars, S50/874, S51/371, 374, 695, 749, S54/954.
anus minor Farran, S51/371, S54/891, 954, S55/660, 672, 721.
irella messinensis (Claus), S51/365, 679, S52/833, S54/479, 960, S55/702, S56/296.
irella bitumida With, S50/54, 219, E52/1196, S53/922, 945, S55/936, S56/262, 368.
irella intermedia With, S51/364, E52/1195, 1314, 1339, S54/949, 960, S55/721.
hirella maxima Wolfenden, E50/135, S50/922, S51/599, 679, 688, 695, E52/1195, 1197, S52/876, S54/891, S55/233.
undina streetsi Giesbr., E50/135, 767, S50/64, 394, S51/364, 851, E52/1314, S53/934, S54/954, S55/233, 672, 660, 702.
euchaeta plumosa (Lubbock), S51/365, 375, S55/702.
euchaeta major Giesbr., S50/855, S51/371, 672, S54/595, S55/721, E56/474.
dochirella obtusa (Sars), E50/135, S50/847.
dochirella pustulifera (Sars), S50/847, S51/364, 374, 375, 679, S54/488, 904.
dochirella notocantha (Sars), S50/68.
aeta acuta Giesbr., S51/363.
uchaeta glacialis (Hansen), S50/68, 425, 540, 847, 867, 874, 949, S51/129, 249, 304, 363, 374, 602, 672, 749, S54/352, S55/948, 963, 971.
uchaeta tonsa (Giesbr.), E50/141, S50/949, S51/312, 371, 374, 375, 695, S54/469, 479, 855.
uchaeta hanseni (With), S51/672, S52/1377.
uchaeta scotti (Farran), S50/425, 847, 949, S51/374.
uchaeta bradyi (With), S51/374.
uchaeta barbata (Brady), E50/135, S50/68, 425, 775, 847, 855, S51/249, 363, 364, 599, 672, 749, E52/1196, S52/141, S53/698, S54/352, S55/941, 963, 971, 972, E56/474, 594.
uchaeta sarsi Farran, E50/135, 138.
uchaeta gracilis (Sars), E50/138, 141, S50/855, S54/479, 488, S55/206.
deuchaeta brevicaudata Sars, S51/304, 364, 602, 679.
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ucalanus chelifer (Thompson), E50/138, 144, S50/783, 847, 855, S51/364, 371, 375, 567, 594, 602, 672, 688, 695, S52/533, S54/343, 469, 516, 954, S56/296.
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Heterorhabdus compactus (Sars), S54/954.
Heterorhabdus spinifrons (Claus), S55/721.
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Auguptilus glacialis Sars, S50/54, 847, S54/954, 959.
Augaptilus longicaudatus (Claus), S51/363, 374, E52/1196, S52/1384, E56/474.
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Euaugaptilus squamatus (Giesbr.), S51/688, 695, S53/77, S54/456.
Euaugaptilus magnus (Wolfenden), S53/944, 953, S54/954, S55/672, E56/474.
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Euaugaptilus affinis Sars, S54/456.
Euaugaptilus filiger (Claus), E50/767, S50/874, S51/374, 375, 688, S53/26, S55/660, S56/296.
Euaugaptilus augustus (Sars), S50/855, S51/364, 570, 599, E52/1197.
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Euaugaptilus hecticus (Giesbr.), S56/262.
Centraugaptilus rattrayi (T. Scott), E50/135, 767, S50/847, E52/1162, 1195, 1197, 1311, 1318, S52/1280, 12
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Centraugaptilus cuculatus (Sars), S55/727.
Centraugaptilus horridus (Farran), S50/400, 855, S51/275, 312, 695, S53/555, 953, 1597, S55/660, 832, 841.
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E52/1196, 1197, S54/479, 960, 987, S55/840, S56/321.
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Pachyptilus eurygnathus (Sars), E50/135, S54/479, 488, S55/672.
Arietellus setosus Giesbr., S53/553, 919, S54/891, S55/233, 672.
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Nesippus boreatis (♂) (Steenstrup and Lutken), E52/1199, 1305, S52/18, 133, S53/332, 554, 917, 935, S54/47
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ıceola loveni Bov., E50/767, S51/364.
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ıa oedicarpus Stebbing, S51/304, 364, 371, 374, 375, 599, 602, 672, 688, 695.
ıa crassicornis (Febr.), S52/1377, S53/934.
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ıa rattrayi Stebbing, E50/767, S50/783, 847, 855, S54/847, S55/672, 721, 840, 936, 941, S56/271.
ıa borealis (Sars), S51/672, 679, 695, 851, E52/1305, S54/453, 891, S56/271, 296.
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ilia propinqua Stebbing, S54/932, 936, 981.
ilia pyripes Bov., S53/924, S54/960, 986, 988, 990, 1181, 1184, 1188.
aumatops fabricii Stebbing, S54/557.
onima sedentaria Forsk., S51/368, S53/2274, S54/946, 949, 962, 986, 1176, 1188, 1366, 1394, S55/723, 753.
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alycaea gracilis Claus, S54/1394, 1395, 1396.
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sidacea
thophausia zoea W-Suhm, S51/364, 695, S54/879, 904.
opia unguiculata W-Suhm, E50/135, S50/855, S51/312, 364, 375, 672, 679, 688, 695, S54/453, 469, 482, 960, S55/672, 721, 840.
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Parapasiphaea sulcatifrons Smith, S54/904, E56/474.

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Peraclis moluccensis Tesch., E56/594.
Spiratella helicoides (Jeffreys), E50/135, S50/847, 855, S51/695, E52/1200, S54/479.
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Carinaria lamarcki Peron & Les., E52/1196, S54/950, 953.
Pterotrachea scutata Gegenbaur, (1959, see text).
Janthina sp., S53/947.

Mollusca—Cephalopoda

Desmoteuthis hyperborea Steenstrup, S55/723, S56/296.
Histioteuthis bonelliana (Ferussac), S50/874.
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Pegea confoederata (Forskål), (1958, see text).
Thetys vagina (Tilesius), (1958, see text).
Doliolina mülleri Krohn, Ch.53c/6.
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Pisces

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Bathylagus spp. E50/138, S50/394, S51/364, E52/1195, 1197, 1200, 1342, S52/876, S53/915, 919, 934, 935, S54/45
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Paralepis coregonoides Risso, E50/135, 138, 767, S51/323, 377, E52/1162, 1195, 1196, 1197, 1200, 1317. S52/87
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Myctophum humboldti (Risso), E52/1193, S54/454, S55/723.
Myctophum punctatum (Rafinesque), E52/1193, S54/454, S55/227.
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Lampanyctus nigrum (Günther), S54/479.
Lampanyctus iselini Parr, S54/904.
Lampadena braueri Zugmayer, S54/904.
Lycodonus flabellicauda Jensen, S56/279.
Melamphaës beanii Günther, S50/855, E56/474.
Melamphaës eurylepis Holt & Byrne, S54/904.
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1684, 1710 (eggs S54/1234).
Antennarius radiosus Garman, (1958, see text).
Diplolychnus bifilis Regan and Trewavas, (1957, see text).
Leptocephali E52/1161, 1162, S52/876, S54/1181, 1187, S55/204, 823, S56/262, 296. 321,

POSITIONS OF STATIONS GIVEN IN APPENDIX TABLE I

(1 METRE NON-CLOSING NETS USED EXCEPT WHERE INDICATED BY *)

No.	Date	Position		Depth (m)
35	27 Mar.	56°50′N	9°50′W	1000–0
38	27 ,,	,,	,,	250
41	27 ,,	,,	9°30′W	600–0
44	27 ,,	,,	,,	250
91	7 June	61°01′N	1°45′E	20
01	20 July	59°31′N	7°05′W	200–0
67	28 Aug.	56°50′N	9°30′W	800–0
70	29 ,,	,,	9°02′W	110–0
28	17 Feb.	60°41′N	0°44′W	90–0
32	20 ,,	59°30′N	1°29′W	75–0
53	7 Mar.	59°17′N	6°53′W	120–0
54	7 ,,	59°44′N	9°15′W	914–0
64	8 ,,	61°35′N	8°53′W	659–0
68	10 ,,	63°18½′N	6°35′W	1188–0
19	12 May	59°44′N	7°15′W	1000–0
27	13 ,,	61°35′N	8°53′W	600–0
94	17 June	60°12′N	7°40′W	591–0
00	17 ,,	61°35′N	8°53′W	700–0
25	19 ,,	63°06′N	6°35′W	1150–0
40	28 ,,	61°21′N	3°10′W	1300–0
71	11 Sept.	61°48′N	9°06′W	250
75	11 ,,	62°15′N	9°30′W	550–0
80	11 ,,	62°04′N	10°48′W	250
83	12 ,,	62°39′N	12°03′W	750–0
88	12 ,,	63°13′N	13°40′W	250
40	20 ,,	63°00′N	18°00′W	250–0
45	21 ,,	62°33′N	17°09′W	170
47	21 ,,	62°07′N	16°06′W	1500–0
55	21 ,,	61°11′N	14°14′W	1500–0
59	22 ,,	60°45′N	13°18′W	170
67	22 ,,	59°50′N	11°24′W	1000–0
74	23 ,,	58°49′N	9°26′W	1500–0
22	4 Nov.	59°17′N	6°53′W	250
27	4 ,,	59°44′N	7°18′W	250
32	4 ,,	59°56′N	7°27′W	100
37	4 ,,	60°23¼′N	7°49½′W	100
49	4 ,,	61°28′N	3°42′W	1150–0
17	14 July	59°31′N	7°05′W	250
74	24 ,,	61°14′N	2°40′W	750–0
79	24 ,,	61°08′N	2°10′W	250
29	19 May	59°17′N	6°53′W	500–0
49	1 June	61°21′N	3°10′W	1000–0
75	16 ,,	59°17′N	6°53′W	580–0
04	19 ,,	59°45′N	11°12′W	1250–0
12	19 ,,	58°46′N	9°18′W	1650–0
23	21 ,,	57°40′N	9°27′W	100
33	23 ,,	,,	15°11′W	250
37	28 ,,	56°25′N	14°16′W	250
57	28 ,,	54°15′N	12°51′W	250–0
58	28 ,,	54°15′N	13°42′W	0
63	28 ,,	,,	14°32′W	1000–250*
64	28 ,,	,,	,,	2120–0
65	29 ,,	,,	16°15′W	250–0
68	29 ,,	,,	17°03′W	0
71	29 ,,	,,	,,	1000–250*
74	29 ,,	53°53′N	15°32′W	2100–0
75	29 ,,	,,	,,	1000–250*
76	30 ,,	53°41′N	14°44′W	250–0
77	30 ,,	53°34′N	14°12′W	250–0

Haul No.	Date	Position		Depth (m)
S51/C'td.				
382	30 ,,	53°25′N	13°43′W	20
383	30 ,,	,,	,,	100
385	30 ,,	53°04′N	12°11′W	0
387	30 ,,	,,	,,	100
567	16 Aug.	59°31′N	7°05′W	250
570	16 ,,	59°44′N	7°15′W	1000–0
589	20 ,,	61°48′N	9°06′W	0
594	20 ,,	62°15′N	9°30′W	500–0
599	21 ,,	62°04′N	10°48′W	250
602	21 ,,	62°36′N	12°03′W	750–0
604	21 ,,	63°13′N	13°40′W	0
672	29 ,,	62°07′N	16°06′W	1750–0
679	30 ,,	61°11′N	14°14′W	1000–0
682	30 ,,	60°18′N	12°20′W	0
688	31 ,,	59°50′N	11°24′W	1100–0
695	31 ,,	58°49′N	9°26′W	1700–0
749	20 Sept.	60°35′N	8°00′W	900–0
850	14 Oct.	59°31′N	7°05′W	50
851	14 ,,	,,	,,	250
907	29 ,,	61°08′N	2°10′W	250–0
910	29 ,,	61°01′N	1°36′W	100
E52/				
60	19 Jan.	58°11′N	2°55′W	30–0
1161	9 June	56°50′N	9°30′W	20
1162	9 ,,	,,	,,	280
1165	10 ,,	,,	9°02′W	20
1174	12 ,,	56°20′N	7°46′W	100
1193	12 ,,	55°30′N	10°21′W	0
1195	12 ,,	,,	,,	250
1196	12 ,,	,,	,,	1000–0
1197	13 ,,	55°28′N	9°42′W	700–0
1198	13 ,,	,,	,,	0
1199	13 ,,	,,	,,	20
1200	13 ,,	,,	,,	250
1203	13 ,,	55°26′N	8°54′W	0
1212	13 ,,	55°35′N	7°46′W	60
1247	15 ,,	54°38′N	5°14′W	20
1248	15 ,,	,,	,,	100
1280	22 ,,	56°41′N	6°40′W	75
1305	24 ,,	58°38′N	8°21′W	500–0
1308	24 ,,	58°53′N	8°50′W	1000–0
1309	24 ,,	,,	,,	0
1311	24 ,,	,,	,,	250
1314	25 ,,	59°36′N	7°11′W	1000–0
1317	25 ,,	,,	,,	250
1318	25 ,,	59°27′N	6°52′W	700–0
1321	25 ,,	,,	,,	250
1339	26 ,,	60°16′N	4°33′W	500–0
1342	26 ,,	,,	,,	250
1756	29 ,,	61°01′N	2°30′W	165
S52/				
18	11 Feb.	61°34′N	7°20′W	150–0
133	19 ,,	61°42′N	4°51′W	0
141	19 ,,	61°21′N	3°10′W	1200–0
533	10 May	59°44′N	7°15′W	960–0
536	11 ,,	59°56′N	7°27′W	250
593	19 ,,	61°21′N	3°10′W	1260–0
610	20 ,,	62°24′N	1°00′W	1500–0
615	20 ,,	61°53′N	,,	250
825	21 June	61°35′N	4°15′W	900–0
833	22 ,,	61°21′N	3°10′W	1350–0
838	22 ,,	61°08′N	2°10′W	100
876	6 July	59°17′N	6°53′W	550–0
886	6 ,,	60°12′N	7°40′W	600–0
902	7 ,,	61°48′N	9°06′W	100
925	11 ,,	64°00′N	6°35′W	2000–0
972	18 ,,	61°14′N	2°40′W	100

Haul No.	Date	Position		Depth (m)
S52/C'td.				
1280	4 Nov.	59°17′N	6°53′W	550–0
1281	4 ,,	59°31′N	7°05′W	150–0
1287	9 ,,	60°23½′N	7°49½′W	150–0
1365	17 ,,	61°54′N	5°45′W	150–0
1377	18 ,,	61°21′N	3°10′W	1900–0
1384	18 ,,	61°08′N	2°10′W	100
1497	8 Dec.	60°30′N	1°57′W	190–0
1502	8 ,,	61°01′N	1°30′W	100
Ch.53/				
4	16 Apr.	48°10′N	7°23′W	60
5	16 ,,	48°06′N	8°24′W	60
6	16 ,,	48°05′N	9°56′W	60
7	17 ,,	47°59′N	12°02′W	60
8	17 ,,	47°54′N	12°56′W	60
9	17 ,,	47°31′N	14°51′W	60
10	18 ,,	46°58′N	16°15′W	60
11	18 ,,	47°07′N	16°35′W	60
12	19 ,,	47°16′N	17°52′W	60
Ch.53b/				
1	25 May	47°50′N	17°40′W	60
3	26 ,,	47°40′N	13°58′W	60
4	26 ,,	47°32′N	12°20′W	60
5	27 ,,	47°33′N	9°57′W	60
6	27 ,,	48°03′N	9°12′W	60
7	27 ,,	48°30′N	8°04′W	60
Ch.53c/				
5	20 June	47°45′N	8°48′W	150
6	20 ,,	47°22′N	9°30′W	150
7	20 ,,	47°92′N	10°06′W	150
8	21 ,,	46°45′N	11°41′W	150
9	21 ,,	,,	12°18′W	150
10	21 ,,	,,	13°22′W	150
11	22 ,,	,,	15°26′W	150
12	22 ,,	,,	16°15′W	150
13	22 ,,	,,	17°28′W	150
14	23 ,,	46°46′N	19°37′W	150
S53/				
17	10 Feb.	59°17′N	6°53′W	550–0
26	10 ,,	59°44′N	7°15′W	950–0
77	17 ,,	62°00′N	6°12′W	110–0
209	17 Mar.	58°30′N	5°45′W	0
282	4 April	61°01′N	0°48′W	0
292	5 ,,	,,	0°44′W	100
332	7 ,,	62°30′N	7°54′W	150
548	11 May	59°17′N	6°53′W	250–0
549	12 ,,	59°44′N	7°15′W	0
553	12 ,,	59°56′N	7°27′W	20
554	12 ,,	,,	,,	250
555	12 ,,	,,	,,	600–0
557	12 ,,	59°59′N	6°52½′W	20
586	23 ,,	61°21′N	3°10′W	650–0
694	13 June	60°12′N	4°18′W	20
695	13 ,,	,,	,,	100
698	13 ,,	60°28′N	5°03′W	920–250*
915	27 ,,	62°08′N	20°18′W	250
917	27 ,,	61°21′N	19°03′W	0
919	27 ,,	,,	,,	250
922	28 ,,	60°32′N	17°55′W	700–0
925	28 ,,	,,	,,	250
929	28 ,,	59°43′N	16°42′W	250
932	28 ,,	58°44′N	15°18′W	0
934	28 ,,	,,	,,	250
935	28 ,,	,,	,,	700–0
939	29 ,,	57°34′N	13°46′W	20
944	29 ,,	57°52′N	12°12′W	1000–300*
945	29 ,,	,,	,,	0
953	30 ,,	58°07′N	10°10′W	700–0
1593	13 Aug.	58°50′N	6°26′W	115–0
1597	14 ,,	59°17′N	6°53′W	590–250*
1611	14 ,,	60°45′N	8°08′W	890–0
1637	17 ,,	61°08′N	2°10′W	250

Haul No.	Date	Position		Depth (m)
S53/C'td.				
1646	18 ,,	60°12′N	1°18′W	100
1648	20 ,,	60°30′N	3°09′W	205–0
1654	22 ,,	58°51′N	7°35′W	100
1657	23 ,,	58°28′N	8°27′W	180–0
1661	23 ,,	57°57′N	9°17′W	0
1667	24 ,,	57°11′N	9°10′W	180–0
1672	25 ,,	56°45′N	8°38′W	20
1697	31 ,,	58°06′N	13°50′W	20
1698	31 ,,	,,	,,	100
1724	16 Sept.	59°25′N	3°25′W	20
1980	17 ,,	59°40′N	2°00′W	95
1990	18 ,,	,,	1°00′W	20
1991	18 ,,	,,	,,	100
2059	20 ,,	58°25′N	2°32′W	60
2207	12 Nov.	58°05′N	0°40′W	100
2238	13 ,,	58°25′N	0°20′W	20
2274	15 ,,	59°15′N	0°30′W	134–0
2277	15 ,,	59°40′N	,,	125–0
2280	15 ,,	,,	,,	100
2288	19 ,,	59°17′N	6°53′W	600–0
2428	10 Dec,	57°25′N	1°20′W	60–0
2537	19 ,,	58°50′N	1°00′W	108–0
E54/				
1265	5 Aug.	61°01′N	3°00′E	0
1279	6 ,,	,,	0°00′	20
1284	6 ,,	,,	1°00′W	20
1608	28 Oct.	58°35′N	3°49′W	38–0
1775	19 Nov.	58°30′N	0°30′W	121–0
S54/				
333	16 Apr.	58°50′N	6°26′W	0
343	17 ,,	59°31′N	7°05′W	500–250–1
352	21 ,,	63°45′N	6°35′W	1000–0
353	21 ,,	63°18½′N	,,	250–0
376	22 ,,	61°28′N	3°42′W	250
378	23 ,,	61°21′N	3°10′W	1200–0
379	23 ,,	61°14′N	2°40′W	250–0
453	13 May	58°07′N	10°10′W	1180–0
454	13 ,,	,,	,,	0
456	13 ,,	,,	,,	250
460	14 ,,	57°52′N	12°12′W	0
461	14 ,,	,,	,,	20
469	15 ,,	58°44′N	15°18′W	1000–0
474	15 ,,	59°43′N	16°42′W	0
475	15 ,,	,,	,,	20
479	16 ,,	60°32′N	17°55′W	1200–0
480	16 ,,	,,	,,	0
482	16 ,,	,,	,,	250
488	16 ,,	62°08′N	20°18′W	1200–0
508	17 ,,	63°00′N	25°10′W	500
516	17 ,,	,,	27°20′W	500
549	21 ,,	64°00′N	,,	500
557	22 ,,	64°30′N	28°25′W	500
563	22 ,,	,,	26°15′W	220
582	29 ,,	65°00′N	27°20′W	300
590	29 ,,	65°30′N	28°25′W	300
595	29 ,,	65°00′N	,,	500
615	30 ,,	65°30′N	33°57′W	0
623	31 ,,	64°38′N	35°15′W	500
696	12 June	59°31′N	7°05′W	250
810	6 July	60°02′N	4°30′W	145
847	9 ,,	60°23½′N	7°49½′W	880–0
849	10 ,,	60°12′N	7°40′W	20
855	10 ,,	59°44′N	7°15′W	900–0
857	10 ,,	59°31′N	7°05′W	250
873	14 ,,	58°32′N	8°50′W	250
876	15 ,,	58°40′N	9°18′W	0
878	15 ,,	,,	,,	250
879	15 ,,	,,	,,	920–0
885	17 ,,	59°31′N	10°43′W	250–0
891	17 ,,	59 45′N	11°12′W	1200–0

No.	Date	Position		Depth (m)
C'td.				
8	17 ,,	60°56′N	13°28′W	250–0
4	19 ,,	61°20′N	14°22′W	1200–0
6	22 ,,	58°18′N	12°32′W	0
3	22 ,,	57°58′N	11°40′W	250
2	15 Aug.	52°40′N	10°40′W	20
4	16 ,,	53°04′N	12°11′W	250–0
6	16 ,,	53°14′N	12°57′W	0
6	17 ,,	53°34′N	14°12′W	250–0
7	17 ,,	,,	,,	0
9	17 ,,	53°41′N	14°44′W	250
0	18 Aug.	53°53′N	15°32′W	250
3	18 ,,	54°05′N	16°18′W	250
4	18 ,,	,,	,,	1200–0
9	18 ,,	54°28′N	18°00′W	250
0	18 ,,	,,	,,	1200–0
1	19 ,,	55°00′N	17°00′W	250–0
2	19 ,,	,,	16°30′W	250–0
9	21 ,,	57°04′N	12°46′W	0
1	21 ,,	,,	,,	250
6	21 ,,	57°00′N	12°00′W	250
7	21 ,,	,,	,,	1200–0
8	21 ,,	,,	11°00′W	250–0
9	21 ,,	,,	10°00′W	0
0	21 ,,	,,	,,	20
1	21 ,,	,,	,,	250
6	14 Oct.	58°50′N	6°26′W	0
1	14 ,,	59°17′N	6°53′W	600–0
3	14 ,,	,,	,,	20
4	14 ,,	,,	,,	250
7	15 ,,	59°31′N	7°05′W	250–0
8	15 ,,	59°44′N	7°15′W	1000–0
4	26 ,,	59°30′N	1°00′W	0
8	15 Nov.	59°15′N	1°00′W	115–0
6	16 ,,	57°45′N	0°30′W	100–0
4	8 Dec.	61°01′N	1°00′E	100
5	13 ,,	,,	1°36′W	140–0
6	13 ,,	61°08′N	2°10′W	250–0
4	28 May	58°30′N	1°30′W	100
2	4 July	60°43′N	0°30′W	110–0
3	31 Oct.	59°15′N	1°30′W	95
1	31 ,,	58°45′N	,,	115–0
6	31 ,,	,,	0°30′W	125–0
9	31 ,,	58°30′N	,,	105–0
2	1 Dec.	57°45′N	1°00′W	91–0
4	2 ,,	58°45′N	0°00′	135–0
0	5 ,,	58°15′N	2°00′W	20
9	15 Feb.	58°50′N	6°26′W	20
1	26 Mar.	58°46′N	7°35′W	0
6	28 ,,	59°30′N	6°20′W	0
9	28 ,,	,,	,,	180
1	23 Apr.	59°31′N	7°05′W	250
4	24 ,,	59°59′N	7°27′W	0
6	24 ,,	,,	,,	250
7	30 ,,	62°34′N	12°47′W	0
3	30 ,,	62°45′N	14°56′W	1100–0
3	17 May	61°21′N	3°10′W	1150–0
5	26 June	60°47′N	2°30′W	220–0
0	5 July	63°05′N	11°42′W	400–200*
2	7 ,,	60°32′N	11°10′W	1000–?*

Haul No.	Date	Position		Depth (m)
S55/ C'td.				
682	8 ,,	59°54′N	14°15′W	1000–400*
700	9 ,,	59°02′N	9°08′W	0
702	9 ,,	,,	,,	250
710	14 ,,	56°46′N	8°52′W	0
721	15 ,,	56°51′N	9°24′W	1100–0
723	15 July	56°59′N	10°00′W	20
727	17 ,,	57°22′N	12°10′W	1100–0
753	20 ,,	59°12′N	10°09′W	20
766	22 ,,	60°35′N	4°30′W	1000–0
832	30 Aug.	59°17′N	6°53′W	625–0
840	31 ,,	59°44′N	7°15′W	1050–0
842	31 ,,	59°06′N	7°27′W	250–0
843	31 ,,	60°12′N	7°40′W	250–0
846	1 Sept.	60°23½′N	7°49½′W	20
848	1 ,,	60°35′N	8°00′W	250–0
862	5 ,,	61°28′N	3°42′W	20
936	3 Nov.	59°17′N	6°53′W	580–0
941	4 ,,	59°44′N	7°15′W	1000–0
948	4 ,,	60°35′N	8°00′W	980–0
949	4 ,,	60°45′N	8°08′W	250–0
963	7 ,,	61°35′N	4°15′W	1040–0
971	7 ,,	61°21′N	3°10′W	1130–0
972	7 ,,	61°14′N	2°40′W	840–0
E56/				
431	8 Aug.	57°25′N	0°55′E	0
459	22 ,,	59°31′N	7°05′W	250
464	23 ,,	59°56′N	7°27′W	0
465	23 ,,	,,	,,	20
466	23 ,,	,,	,,	250
471	24 ,,	60°23½′N	7°49½′W	250
472	24 ,,	60°45′N	8°08′W	250–0
474	30 ,,	62°25′N	14°12′W	1475–0
475	30 ,,	62°42′N	14°43′W	250–0
567	22 Oct.	60°32′N	3°32′W	400–0
586	11 Nov.	59°17′N	6°53′W	545–0
594	11 ,,	59°44′N	7°15′W	1000–0
595	11 ,,	59°56′N	7°27′W	250–0
596	11 ,,	60°12′N	7°40′W	250–0
601	12 ,,	60°35′N	8°00′W	250–0
604	12 ,,	60°54′N	8°16′W	100–0
634	18 ,,	61°21′N	3°10′W	1200–0
S56/				
31	4 Apr.	61°01′N	0°00′	0
262	18 July	59°17′N	6°53′W	800–0
265	18 ,,	59°31′N	7°05′W	250
270	18 ,,	59°54′N	7°15′W	250
271	18 ,,	,,	,,	800–0
278	18 ,,	60°23½′N	7°49½′W	250
279	18 ,,	,,	,,	900–0
296	21 ,,	60°54′N	12°10′W	800–0
315	23 ,,	59°12′N	10°00′W	0
321	24 ,,	59°01′N	9°25′W	800–0
327	28 ,,	58°27′N	8°00′W	100
328	29 ,,	57°44′N	9°05′W	0
330	29 ,,	,,	,,	25
335	30 ,,	57°40′N	10°50′W	800–0
337	30 ,,	,,	,,	15
368	6 Aug.	60°25′N	4°35′W	800–0
371	6 ,,	,,	3°45′W	100–0
377	7 ,,	60°50′N	2°35′W	100
382	7 ,,	61°27′N	2°25′W	800–0

Table II

MODERATELY COMMON ORGANISMS EXCLUDED FROM APPENDIX TABLE I

Medusae
Leuckartiara octona (Fleming)
Neoturris pileata (Forskål)
Laodicea undulata (Forbes and Goodsir)
Staurophora mertensii Brandt
Mitrocomelle polydiademata (Romanes)
Cosmetira pilosella Forbes
Halopsis ocellata Agassiz
Phialidium hemisphericum (L.)
Rhopalonema velatum Gegenbaur
Solmaris corona (Kerf. and Ehlers)
Pelagia noctiluca (Forskål)

Siphonophora
Hippopodius hippopus (Forskål)
Lensia conoidea (Kerf. and Ehlers)
Sulculeolaria (*Galetta*) *biloba* (Sars)
Dimophyes arctica (Chun)
Chelophyes appendiculata (Eschscholtz)
Agalma elegans (Sars)
Nanomia cara (Delle Chiaje)
Physophora hydrostatica Forskål

Chaetognatha
Sagitta serratodentata Krohn
S. maxima (Conant)
S. zetezios Fowler
Eukrohnia hamata R.-Z.

Polychaeta
Tomopteris helgolandica Greeff
Tomopteris septentrionalis Quart.

Ostracoda
Conchoecia borealis Sars
C. haddoni Brady and Norman
C. elegans Sars
C. daphnoides (Claus)
Halocypris globosa (Claus)

Copepoda
Calanus hyperboreus Kröyer
Eucalanus elongatus Dana
Rhincalanus nasutus Giesbrecht
G. tenuispinus Sars
Gaidius affinis Sars
Gaetanus pileatus Farran
G. kruppi Giesbrecht
Euchirella rostrata (Claus)
E. curticaudata Giesbrecht
Pareuchaeta norvegica (Boeck)
Euchaeta hebes Giesbrecht
Metridia longa (Lubbock)
Pleuromamma robusta (Dahl)
Anomalocera patersoni Templeton

Amphipoda
Themisto spp. (except *T. libellula*)
Hyperia spp.
Hyperoche medusarum (Kröyer)
Hyperoides longipes Chevreux

Euphausiacea
Meganyctiphanes norvegica (M. Sars)
Thysancessa inermis (Kröyer)
T. longicaudata (Kröyer)
T. raschii (M. Sars)
Nyctiphanes couchii (Bell)

Decapoda
Sergestes atlanticus M.-Edw.
S. articus Kröyer
Pasiphaea sivado (Risso)

Mollusca
Spiratella retroversa (Fleming)
Clione limacina (Phipps)
Euclio pyramidata (L.)
Pneumodermopsis ciliata (Gegenb.)
Gonatus spp.
Tracheloteuthis riseii Steenstrup

Fish
Benthosema glaciale (Reinhardt)
Electrona arcticum (Lütken)
Maurolicus mulleri (Gmelin)
Cyclothone spp.

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